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Human Factors Assessment of the UH-60M Crew Station During the Limited User Test (LUT)

by Thomas J. Havir, David B. Durbin, Lorraine J. Frederick, and Jamison S. Hicks

ARL-TR-3730 **February 2006**

NOTICES

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Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5425

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14. ABSTRACT
The utility helicopter (UH)-60M Product Manager requested the U.S. Army Research Laboratory's Human Research and Engineering Directorate to participate in the Limited User Test for the UH-60M Black Hawk. ARL conducted a human factors evaluation during the LUT, which assessed workload, situation awareness, simulator sickness, pilot-vehicle interface, and eye tracker data. The data were used to identify characteristics of the UH-60M that enhance or degrade pilot performance. Characteristics that degrade pilot performance were included in the Manpower and Personnel Integration (MANPRINT) assessment for the system's milestone decision and should be considered for future design changes at the earliest opportunity.

Three UH-60 crews (six pilots) each conducted six mission scenarios for a total of 18 flights. The conditions of each mission were systematically varied and designed to become progressively more difficult as the pilots became more proficient at flying the aircraft. The pilots completed the simulator sickness questionnaire before and after each flight. They completed the Bedford Workload Rating Scale, Situation Awareness Rating Technique, and the Pilot-Vehicle Interface Questionnaire after each mission. In addition to pilot data, a tactical steering committee (TSC) performed an independent assessment of workload, situation awareness, and mission success. The TSC completed a survey after each mission. The data were analyzed with the use of the Wilcoxon Signed Ranks Test to compare pilot ratings between seat position and results between UH-60M and UH-60A/L model aircraft.

The mean workload rating for all tasks for the UH-60M was 2.71, indicating that the pilots typically had enough workload capacity for all desirable additional tasks. The mean situation awareness rating provided by the pilots was 28.25. This SA rating indicates that the pilots felt they had high levels of situation awareness during the missions. The pilots also provided data and comments regarding the pilot-vehicle interface and offered recommendations for design improvements. Finally, the eye tracker results showed that the flying pilot was focused out the window 85.60% of the time while the non-flying pilot spent only 28.21% focused out the window.

The results indicated that the UH-60M crew station resulted in acceptable workload and SA levels and offers significant improvements compared to the UH-60A/L. However, several issues were identified which, if corrected, could offer further reductions in workload and improve pilot performance. These issues should be considered for future modifications of the UH-60M design, and future human factors evaluations should be conducted to evaluate the effectiveness of any design changes.

15. SUBJECT TERMS
Black Hawk; CAAS; human factors; pilot workload; UH-60

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The authors would like to thank Mr. Dan Kern of the UH-60M Product Manager's Office (PMO) for giving us the opportunity to participate in this evaluation and to provide critical human factors data to the PM. We would also like to recognize Mr. Nick Nickles who works as a contractor for Quantitech in support of the UH-60M PMO. Nick was very helpful in preparing for this test and helped create the surveys required to collect the human factors data.

Two members of the U.S. Army Test and Evaluation Command were significant to the success of the LUT: Major Chris Lynch was the Army evaluator for the Army Evaluation Center. Major Lynch worked closely with the human factors community to ensure that all human factors requirements were adequately addressed in the system evaluation plan. Captain Dave Cheney served as the Operational Test Command's test officer for the LUT. Captain Cheney was responsible for the execution of the LUT and assisted in collecting human factors data during the test.

The authors would like to thank all the members of the Software Engineering Directorate and the Systems Simulation Development Directorate of the U.S. Army Aviation and Missile Command (AMCOM) at Redstone Arsenal, Alabama, for their valuable technical expertise during the LUT. Their hard work contributed to the success of the Software Integration Laboratory during the test. Special thanks go to Eric Fendley, Dena Childress, and Eric Thomas of AMCOM's Aviation and Missile Research, Development, and Engineering Center (AMRDEC) for their valuable assistance in preparing for and collecting eye tracker data during the LUT.

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Finally and most importantly, our thanks to our six participants, who shall remain unnamed for scientific protocol reasons. Professional Army aviators all, they and their comrades are the reason all of us work so diligently on this aircraft.

1. Introduction

1.1 Background and Purpose

The utility helicopter (UH)-60 Black Hawk is a twin-turbine engine, single rotor, semimonocoque fuselage, rotary wing helicopter capable of transporting cargo, 11 combat troops, and weapons during day, night, instrument meteorological conditions (IMC), visual meteorological conditions (VMC), and degraded visual environmental conditions (see figure 1). The main and tail rotor systems consist of four blades each, with the capability to manually fold the main rotor blades, scissor the tail rotor paddles, and fold the tail pylon assembly for deployment, transport, or storage. A movable, horizontal folding stabilator assembly is situated on the lower portion of the tail rotor pylon to provide enhanced flight characteristics.

Figure 1. UH-60M Black Hawk helicopter.

The UH-60 Black Hawk helicopter provides air assault, general support, and medical evacuation (MEDEVAC) capabilities for the U.S. Army. The UH-60 also supports the Army Airborne Command and Control System and special operations. The UH-60A and UH-60L model Black Hawk helicopters were first fielded in the 1970s and are approaching the end of their useful service life. Increasing operations and support costs and decreasing operational readiness are consequences of the aging fleet. The UH-60M program, formerly a recapitalization program of existing airframes, is now a new production program designed to improve the life of the current system, reduce operations and support costs, and increase operational readiness. Additionally, the UH-60M will meet future digitization and situational awareness (SA) requirements, increase the lift and range capabilities of the current aircraft, and provide an improved platform for the HH-60M MEDEVAC helicopter.

Many significant changes in the helicopter are in the UH-60M cockpit (see figure 2). Four multi-function displays (MFDs) are placed in a smaller dashboard, 6 inches narrower than on the current UH-60, which provides additional visibility outside the cockpit, thereby enhancing safety. The MFDs will display primary flight instruments that replace the traditional analog

instruments and a digital map that will provide tactical and navigational information to the pilots, significantly enhancing SA. In addition, a flight management system (FMS) is used to manage voice and digital communication, navigation, and flight planning.

Figure 2. Artist's rendering of the UH-60M Black Hawk crew station.

The U.S. Army Operational Test Command conducted a successful Limited User Test (LUT) in support of the low rate initial production decision in the second quarter of fiscal year 2005. The LUT was focused on evaluating the pilot-vehicle interface (PVI), and the primary purpose was to provide input to the U.S. Army Evaluation Center's system evaluation report. The data were also used by ARL's Human Research and Engineering Directorate (HRED) to draft the Manpower and Personnel Integration (MANPRINT) assessment.

At the request of the UH-60M Project Manager's Office (PMO), ARL's HRED conducted a human factors evaluation (HFE) of the UH-60M crew station during the LUT. The HFE focused on workload, SA, and PVI. Additional data collection included eye tracker data, simulator sickness data, and tactical steering committee (TSC) ratings of workload, SA, and mission success.

The purpose of this report is to summarize the human factors data collected during the LUT by ARL.

1.2 Assessment of Crew Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the mental and physical ability of the crew to effectively perform their flight and mission tasks. If one or both pilots experience excessively high workload while performing flight and mission tasks, the tasks may be performed ineffectively or abandoned. In order to assess whether the pilots are task overloaded during the mission profiles, the level of workload for each pilot must be evaluated.

1.2.1 Bedford Workload Rating Scale

The pilots completed the Bedford Workload Rating Scale (BWRS) (appendix A) immediately after each mission to estimate the level of workload that they experienced during missions. The pilots also provided workload estimates for what they felt the workload would be performing the same tasks in a UH-60A/L. The pilots used the BWRS to rate the workload needed to accomplish 32 UH-60M aircrew training manual (ATM) tasks (appendix A). The ATM tasks were selected by personnel from ARL, the UH-60M PMO, and the Training and Doctrine Command (TRADOC) System Manager (TSM) for utility aircraft because they were estimated to have the most impact on pilot workload during the planned missions.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation (Roscoe & Ellis, 1990). It requires pilots to rate the level of workload associated with a task, based on the amount of spare capacity they feel they have to perform additional tasks. Spare workload capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots often perform navigational tasks, communicate via multiple radios, monitor aircraft systems, and assist the pilot with the controls with flight tasks (e.g., maintain air space surveillance) within the same time interval. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Integration of the UH-60M crew station should help ensure that pilots can maintain adequate spare workload capacity while performing flight and mission tasks.

1.3 Assessment of Crew Situational Awareness (SA)

SA can be defined as the pilot's mental mode of the current state of the flight and mission environment. A more formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). It was important to assess SA during the LUT because it had a direct impact on pilot and system performance. Good SA should increase the probability of good decision making and performance by air crews when they perform flight and mission tasks in the UH-60M.

1.3.1 Situation Awareness Rating Technique (SART)

The SART (appendix B) is a multi-dimensional rating scale for operators to report their perceived SA. The SART was developed as an evaluation tool for the design of air crew systems (Taylor, 1989) and examines three components of SA: understanding, supply, and demand. Taylor proposed that SA depends on the pilot's understanding (U) (e.g., quality of information he receives), and the difference between the demand (D) on the pilot's resources (e.g., complexity of mission) and the pilot's supply (S) (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

1.4 Assessment of Pilot-Vehicle Interface (PVI)

The crew station PVI directly impacts crew workload and SA during a mission. A crew station that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. The pilots completed a PVI questionnaire after each mission (appendix C) to identify any problems with the usability of the controls, displays, or subsystems.

1.5 Assessment of Simulator Sickness

Simulator sickness has been defined as a condition when pilots suffer physiological discomfort in the simulator but not while flying the actual aircraft (Kennedy, Lilienthal, Berbaum, Balzley, & McCauley, 1989). It is generally believed that simulator sickness is caused by a mismatch between the visual and vestibular sources of information about self-motion or between the sensory information (e.g., acceleration cues) presented by the simulator and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Characteristics of simulator sickness include nausea, dizziness, drowsiness, and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). If pilots are distracted by the discomfort they feel during missions, their performance is likely to suffer. Additionally, the discomfort could influence the perceived levels of workload and SA that the pilots experienced during a mission.

1.5.1 Simulator Sickness Questionnaire (SSQ)

The SSQ (appendix D) was administered to the pilots to estimate the severity of physiological discomfort that they experienced during missions and to help assess whether they were being distracted by the discomfort. The SSQ (Kennedy, Lane, Berbaum, & Lilienthal, 1993) is a

checklist of 16 symptoms that are categorized into three subscales: oculomotor (e.g., eyestrain, difficulty focusing, blurred vision), disorientation (e.g., dizziness, vertigo), and nausea (e.g., nausea, increased salivation, burping). The three subscales are combined to produce a total severity score. This score is an indicator of the overall discomfort that the pilots experienced during the mission.

1.6 Tactical Steering Committee (TSC)

A TSC observed each mission and rated crew workload, crew SA, crew coordination, and mission success (appendix E). The TSC provided an independent assessment of the workload and SA levels experienced by the crews. They also helped identify whether problems with crew workload or crew SA contributed to lack of mission success.

TSC personnel observed each mission from the battle master station in the Systems Integration Laboratory (SIL) located at the Software Engineering Directorate (SED) of the U.S. Army Aviation and Missile Command (AMCOM) at Redstone Arsenal, Alabama, where they could observe crew station displays and the out-the-window (OTW) view provided to the crew (see figure 3). They also listened to all audio communications between crew members and outside sources during the missions. A large projection map provided real-time status of the location of the aircraft on the terrain database.

Figure 3. Battle master station.

1.7 Aviation and Missile Command, Software Engineering Directorate

The SIL offered the appropriate capability required to conduct the LUT in a simulated environment. SED is a recognized leader in supporting the acquisition, research, development, and sustainment of some of many sophisticated weapon systems. SED maintains expertise in the

Army's prevailing policies on acquisition. These policies include software reuse, software metrics, post-deployment software support, process improvement, computer resource margins analysis, and risk management.

SED's risk-based approach to performing verification and validation (V&V) is designed to focus on identified problem areas, to ensure effective software engineering support with minimum cost. Using the facilities and the numerous tactical hardware and software laboratories, SED provides weapon systems with the highest quality support in the areas of joint interoperability testing and engineering.

1.7.1 Systems Integration Laboratory (SIL)

One of the simulation resources within the SED is the SIL. The UH-60M SIL was composed of four main components: tactical systems, data monitoring and collection systems, user control system, and simulation systems (see figure 4). When combined, these components provided a UH-60M cockpit environment coupled to the aircraft's external environment. The cockpit was incorporated into the forward section of a UH-60L aircraft. Using a section of the actual aircraft enabled us to provide a realistic environment with production-representative hardware. This enabled the human factors and MANPRINT experts to provide a thorough evaluation during the LUT (see figure 5).

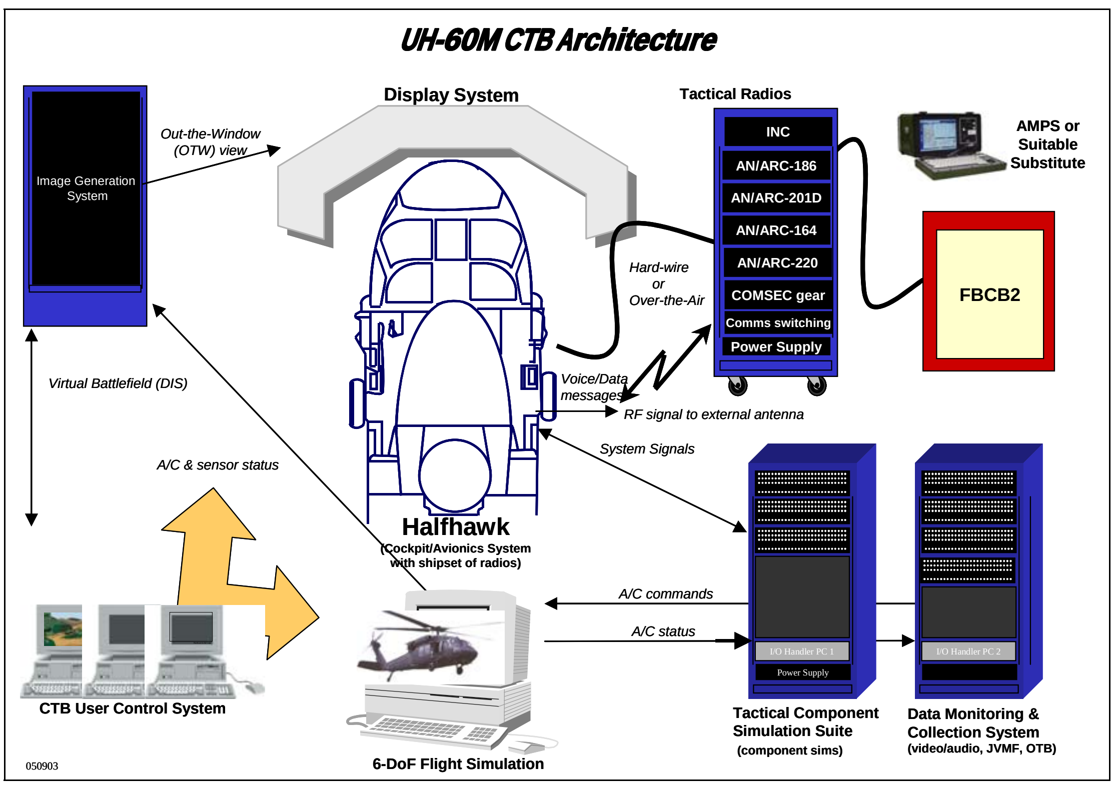

Figure 4. UH-60M SIL architecture.

Figure 5. Photograph of SIL crew station.

2. Method

2.1 Participants

Participants consisted of six male UH-60 pilots. One pilot was a Chief Warrant (CW) 3 battalion standards pilot with the 1-212 Aviation Regiment at Fort Rucker, Alabama. Two pilots were instructor pilots from the same unit and held the ranks of CW2 and CW3. One pilot was a civilian, instructor pilot for the maintenance test pilot course at Fort Rucker. Two pilots were Army pilots stationed at Fort Campbell, Kentucky. One held the rank of captain and served as the assistant S-3 officer for the 4-101 Aviation Regiment. The other pilot was a CW2 and was a member of the 5-101 Aviation Regiment. These pilots represented a broad range of experience with total flight hours that ranged from 180 to 4141. The demographic characteristics of the pilots are listed in table 1.

Table 1. Pilot demographics (N = 6).

Summary of demographic characteristics	Age (yrs)	Flight hours in UH-60A/L Black Hawk	Total flight hours in Army aircraft
Mean	34.3	1760	2059
Median	33.5	1569	2196
Range	25 to 46	140 to 3848	180 to 4141

Anthropometric data were also collected for each pilot. Ten critical measurements were taken for each pilot, including stature, bideltoid breadth, chest depth, butt-knee length, interpupillary breadth, functional leg length, hand length, hand breadth, thumb tip reach, and sitting eye height (Gordon & Donelson, 1991). These measurements were taken to ensure that the participants represented a broad range of the intended user population with respect to human dimensions. Table 2 shows the dimensions for each anthropometric measurement.

The TSC consisted of two personnel with extensive Army aviation experience. One was the TRADOC System Manager user representative from Fort Rucker and held the rank of CW3. The other was a captain who was currently serving as the Operational Test Command test officer for the UH-60M LUT.

Table 2. Anthropometric measurements.

	Pilot 1 (cm)	Pilot 2 (cm)	Pilot 3 (cm)	Pilot 4 (cm)	Pilot 5 (cm)	Pilot 6 (cm)	Percentile Range
Sitting Eye Height	81.3	81.4	80.5	80.5	84.2	82.4	43 to 84
Thumb Tip Reach	79.8	86.8	80.0	84.2	87.4	83.0	43 to 97
Hand Breadth	9.0	9.1	8.7	9.1	9.6	8.8	22 to 93
Hand Length	20.4	23.7	19.8	21.4	20.4	18.3	9 to 99
Functional Leg Length	110.6	119.7	110.0	110.8	118.8	105.1	24 to 99
Interpupillary Breadth	61.5	62.5	59.0	69.0	65.0	58.0	4 to 93
Butt-Knee Length	62.5	66.5	62.9	62.1	67.4	58.8	12 to 98
Chest Depth	26.4	32.0	24.4	28.7	34.4	21.8	5 to 99
Bideltoid Breadth	49.9	55.5	50.1	56.2	51.3	46.7	10 to 99
Stature	178.4	184.5	179.8	176.0	186.4	178.4	44 to 93

2.2 Data Collection

The BWRS, SART, PVI, SSQ, and TSC questionnaires (appendices A through E) were developed in accordance with published guidelines for proper format and content (O'Brien & Charlton, 1996). A pre-test was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots and TSC members.

The pilots completed the PVI, workload, and SA questionnaires immediately after each mission. The pilots completed the SSQ before and after each mission. TSC members completed the TSC questionnaire after each mission. Additional data were obtained from the pilots and TSC members during post-mission discussions and the final after-action review (AAR). Questionnaire results were clarified with information obtained during post-mission discussions and the daily AARs.

2.2.1 Eye Tracker System

Although the data from the questionnaires were systematically gathered by widely accepted HFE methods, they were still subjective in nature. Complementary objective data were collected through a head and eye tracking system from Applied Science Laboratories (ASL). Their system was used because it was capable of integrating a laser head tracker to allow unrestricted head movement during data collection and it was compatible with the head gear unit (HGU)-56 flight helmet. The EyeHead[1] Package integrated a Model 501 eye tracker and a Laserbird[2] head tracker. This technology allowed us to collect digital data that specify point of gaze with respect to stationary objects within the crew station. The ASL software allowed data collectors to continuously monitor the eye position of the pilots by crosshairs superimposed over live imagery (see figure 6). The software also included a built-in analytical tool that allowed data to be viewed in tabular or graphical format.

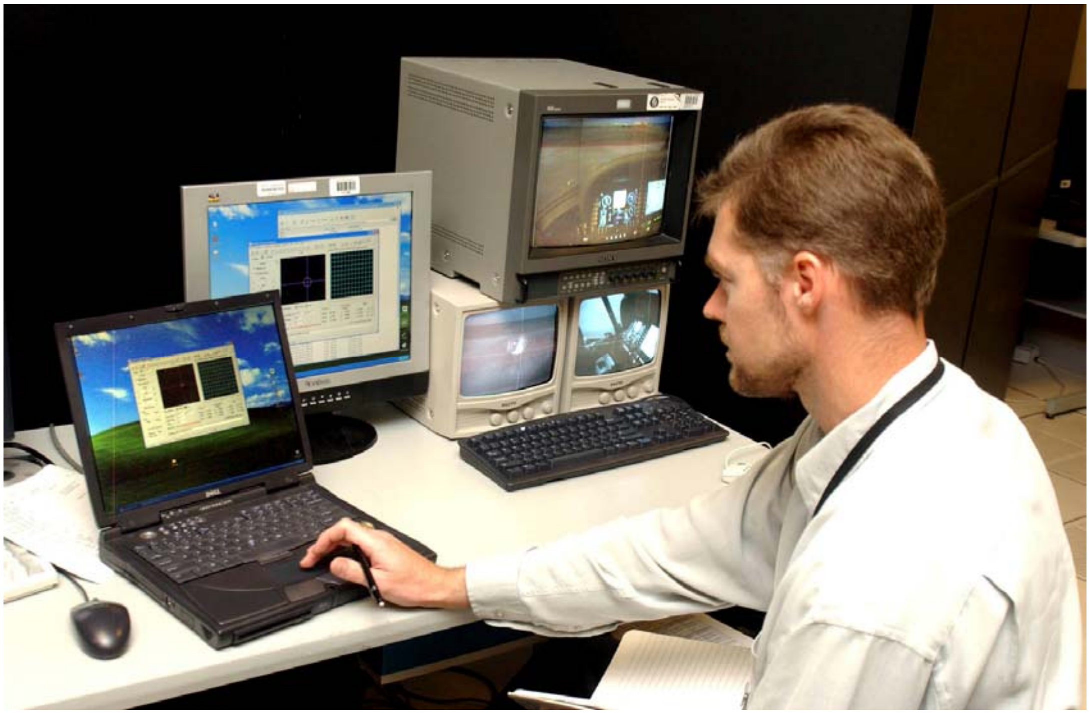

Figure 6. Eye tracker scene camera monitors and control panel interface.

[1]EyeHead is a trademark of ASL.
[2]Laserbird is a trademark of Ascension Technology Corp.

2.3 Data Analysis

Pilot responses to the BWRS, SART, SSQ and PVI questionnaires were analyzed with means and percentages. Their responses to the BWRS, SART, and SSQ were further analyzed with the Wilcoxon Signed Ranks Test (WSRT) to compare pilot ratings between seating position (left versus right) and aircraft model (M versus A/L). The WSRT was used to calculate probability values for data comparisons.

We summarized the eye tracker data by calculating the total percentage of mission time spent focused on different areas of interest (AOIs). There were periods of the mission when no eye tracker data were collected or the data collected were unusable because the calibration was disturbed; therefore, for the purpose of analyzing eye tracker data, the mission time is defined as the time during the mission when useful eye tracker data were collected. Four AOIs were created for each pilot: left MFD, right MFD, OTW, and other (see figure 7). The "other" category captured eye fixations focused on areas not captured by the other AOIs. The FMS and pilot's kneeboard were both captured in this category.

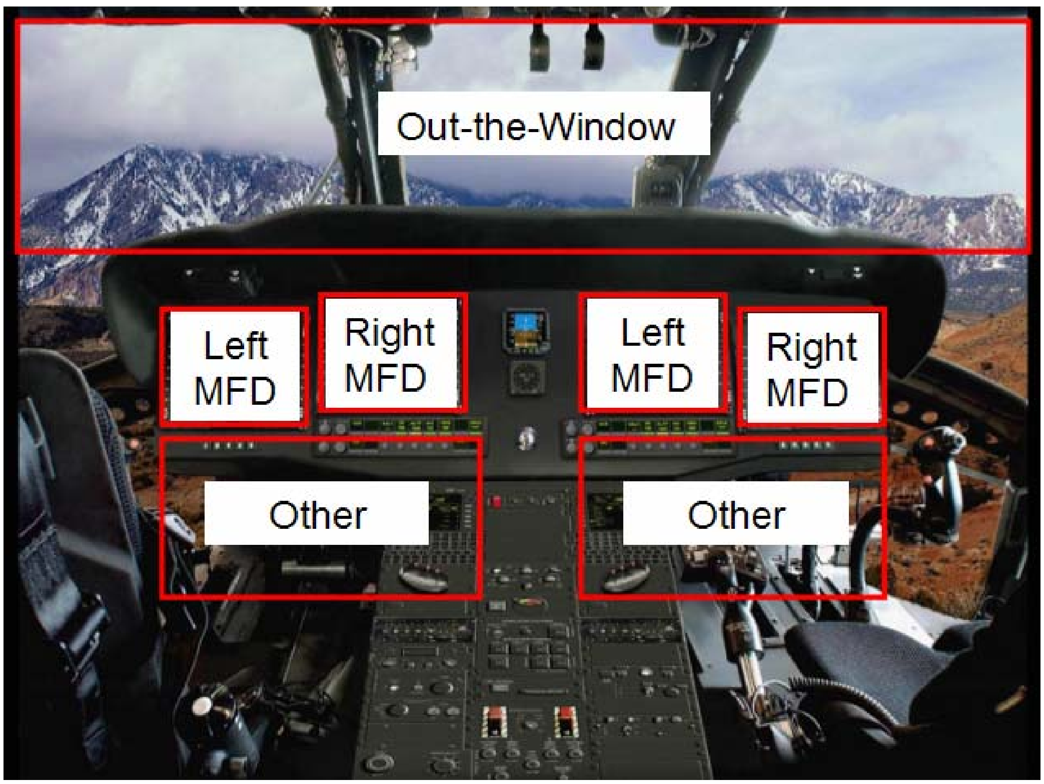

Figure 7. Eye tracker areas of interest.

The eye tracker data were complicated during the LUT because the pilots were allowed to alternate flying responsibilities throughout the flight. Since the eye tracker data are typically separated by flying versus non-flying pilot, this made analysis of the data much more difficult. Additionally, the mission scenarios included single-ship and multi-ship missions. During multi-ship missions, the lead aircraft is responsible for maintaining altitude and air speed. Trail aircraft

maintain their position relative to the aircraft in front of them. We assumed there would be a significant difference between single-ship and multi-ship eye tracker data, so the data were segregated according to these two mission types.

2.4 Limitations of Assessment

The SIL had several limitations that restricted the human factors experts from performing a full assessment of the UH-60M crew station. The SIL was a non-motion simulator. During actual flight, gravitational forces contribute to the pilot's SA. The effects of the motion and vibration can also affect pilot performance and the ability to clearly read the aircraft instruments. The lack of motion limited the pilot's ability to perform a comprehensive evaluation of SA, workload, and readability of displays.

The SIL was not equipped with a landing light or searchlight. This limitation prevented flight scenarios from being conducted in night, unaided conditions. The effects of natural sunlight could not be replicated in the SIL. This limited the ability to evaluate the readability of the displays during high illumination conditions. In addition to sunlight, other natural environmental conditions, such as noise levels, temperature, and humidity, were not representative of an actual aircraft in a southwest Asia scenario.

Only two types of joint variable message format (JVMF) messages were available during the LUT. This limited the ability to fully evaluate the workload associated with sending and receiving digital messages.

Lack of available time and resources made it infeasible to conduct simulated flights in an A or L model UH-60 to collect workload data. As a result, in order to complete a workload comparison between the UH-60M and previous model UH-60s, participants estimated what they thought workload might be for each task if they performed it in a UH-60A/L. This lack of "real" workload data for the UH-60A/L somewhat limits the usefulness of the comparison.

2.5 Test Schedule and Description of Mission Scenarios

The first phase of the evaluation was pilot training. This training occurred from July 19 to July 30, 2004. Members of the PMO conducted the training to teach the pilots how to operate the UH-60M and the limitations of the SIL. Training consisted of classroom training and flight time in the simulator. The second phase of the LUT was the test phase that occurred from August 2 to August 27, 2004. Each crew conducted six vignettes in accordance with the operational mode summary and mission profile (OMS/MP). The six vignettes were designed to become progressively more difficult as the pilots became more proficient at flying the UH-60M. A description of the vignettes is shown in table 3.

Table 3. Vignette descriptions and conditions.

Vignette Number	Description	Conditions
1	Entry into Theater	Day, Single-Ship, MOPP 0, VMC/IMC
2	Air Assault	Day, Multi-Ship, MOPP 0, VMC
3	Air Movement	Day, Single-Ship, MOPP 4, VMC
4	Landing Strip Seizure	Day, Multi-Ship, MOPP 4, VMC
5	Air Movement – High Gross Weight	Night, Single-Ship, MOPP 0, VMC/IMC, NVG
6	Long Range Surveillance Detachment	Night, Multi-Ship, MOPP 4, VMC, NVG

MOPP = mission-oriented protective posture

The test schedule consisted of one test flight each day. The crew began each day attending a mission briefing presented by the Directorate of Combat Developments (DCD) user representative. After the crew acknowledged the briefing, they prepared for and conducted the mission in the SIL. Immediately after each mission, the crew members were relocated to a data collection room where they completed the human factors surveys. After the crew completed the surveys, the test team conducted an AAR. At the end of the test, all the pilots participated in a final, comprehensive AAR.

3. Results

3.1 Crew Workload

3.1.1 Mean Workload Ratings for ATM Tasks

The mean overall workload rating for all ATM tasks for the UH-60M was 2.71. The mean workload rating for the same tasks, assuming they were performed in a UH-60A/L, was 3.99. This difference between workload ratings given for the UH-60M and the UH-60A/L was statistically significant (WSRT, z = -2.201, $p = 0.028$) (see figure 8). The practical significance of this difference is also noteworthy because the mean workload rating for the UH-60M indicates that workload was satisfactory without a reduction in spare workload capacity while the rating for the UH-60A/L indicates that workload is not satisfactory and results in a reduction in spare workload capacity.

The UH-60M workload ratings were also compared between seat positions. The mean UH-60M workload ratings for the left and right seat positions were 2.80 and 2.58, respectively. The difference between seat positions was not statistically significant (WSRT, z = -0.943, $p = 0.345$).

Two tasks received peak workload ratings of 6, indicating that workload was not tolerable for the task. These tasks included maintaining air space surveillance and transmitting tactical reports. Pilots indicated that both tasks received high workload ratings because of the difficulty involved with performing JVMF messaging, causing increased workload and decreasing the time available

to perform airspace surveillance. Appendix F includes a table of mean workload ratings for all tasks. A set of pilot comments regarding workload is included in appendix G.

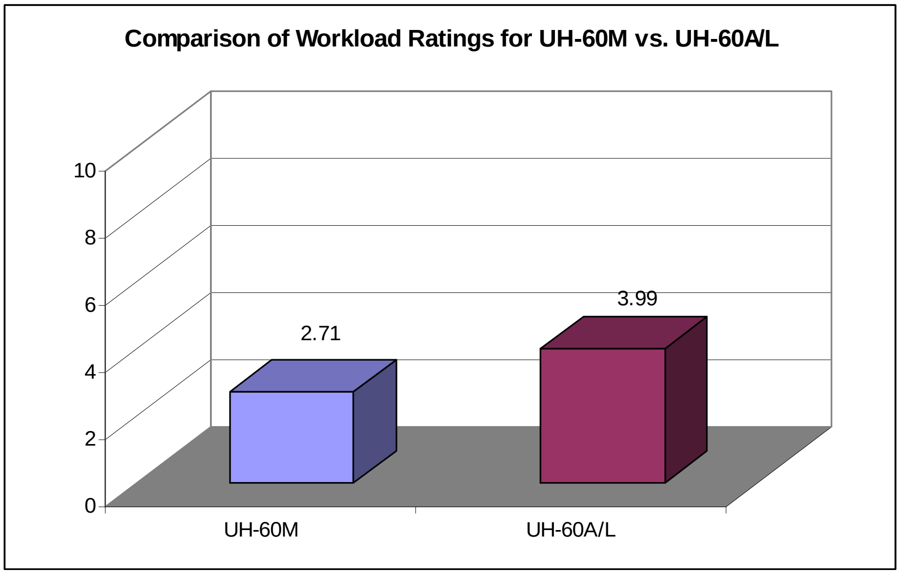

Figure 8. Comparison of workload ratings for UH-60M versus UH-60A/L.

3.1.2 TSC Ratings for Workload and Crew Coordination

The TSC provided an overall mean workload rating of 2.91 for pilots sitting in either crew position. An overall mean rating of 2.91 indicates that the pilots typically had "enough workload capacity for all desirable additional tasks". The TSC also gave individual ratings for pilots in each seat. The workload ratings for the left and right seats were 2.99 and 2.83, respectively. Overall, the results indicate that workload was adequately divided between the two crew members.

The TSC also rated crew coordination for each mission using a 5-point rating scale. The mean crew coordination rating for all missions was 1.83 (see figure 9).

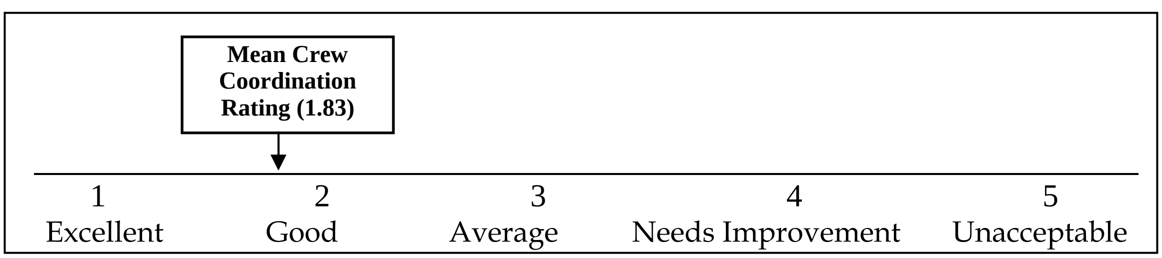

Figure 9. Overall TSC crew coordination ratings.

3.2 Crew Situational Awareness

3.2.1 SA Ratings by the Subjects

The overall SART score provided by the pilots was 28.25 for the UH-60M. This score indicates that the pilots felt they had high levels of overall SA during the missions. The pilots also provided an SA rating for the UH-60A/L of 11.69. An SA rating of 11.69 indicates that the pilots felt they experienced moderate levels of SA during the mission. The difference between SA ratings for the UH-60M and UH-60A/L was statistically significant (WSRT, $z = -2.201$, $p = 0.028$) and is depicted in figure 10. The pilots indicated that the improved SA in the UH-60M was primarily attributable to the digital map.

The SA ratings for the UH-60M were compared by seat position. The SA ratings for the left and right seats were 28.28 and 28.22, respectively. The difference between SA scores for the left and right seats was not statistically significant (WSRT, $z = -0.674$, $p = 0.500$) and indicates that both pilots had high SA during the missions.

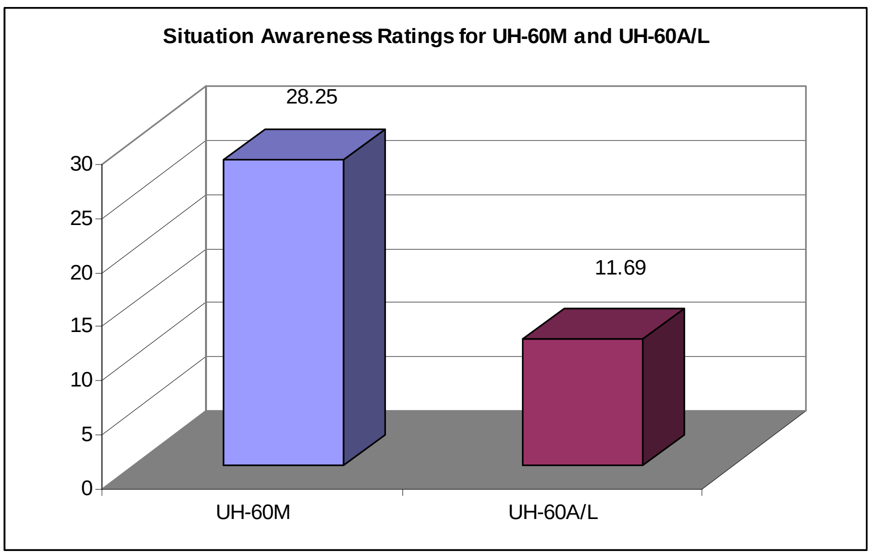

Figure 10. Overall SART scores for UH-60M and UH-60A/L.

Figure 11 shows the subscale ratings for the UH-60M and UH-60A/L. Figure 12 shows the subscale ratings for the left and right seats of the UH-60M. Pilot SA comments are presented in appendix H.

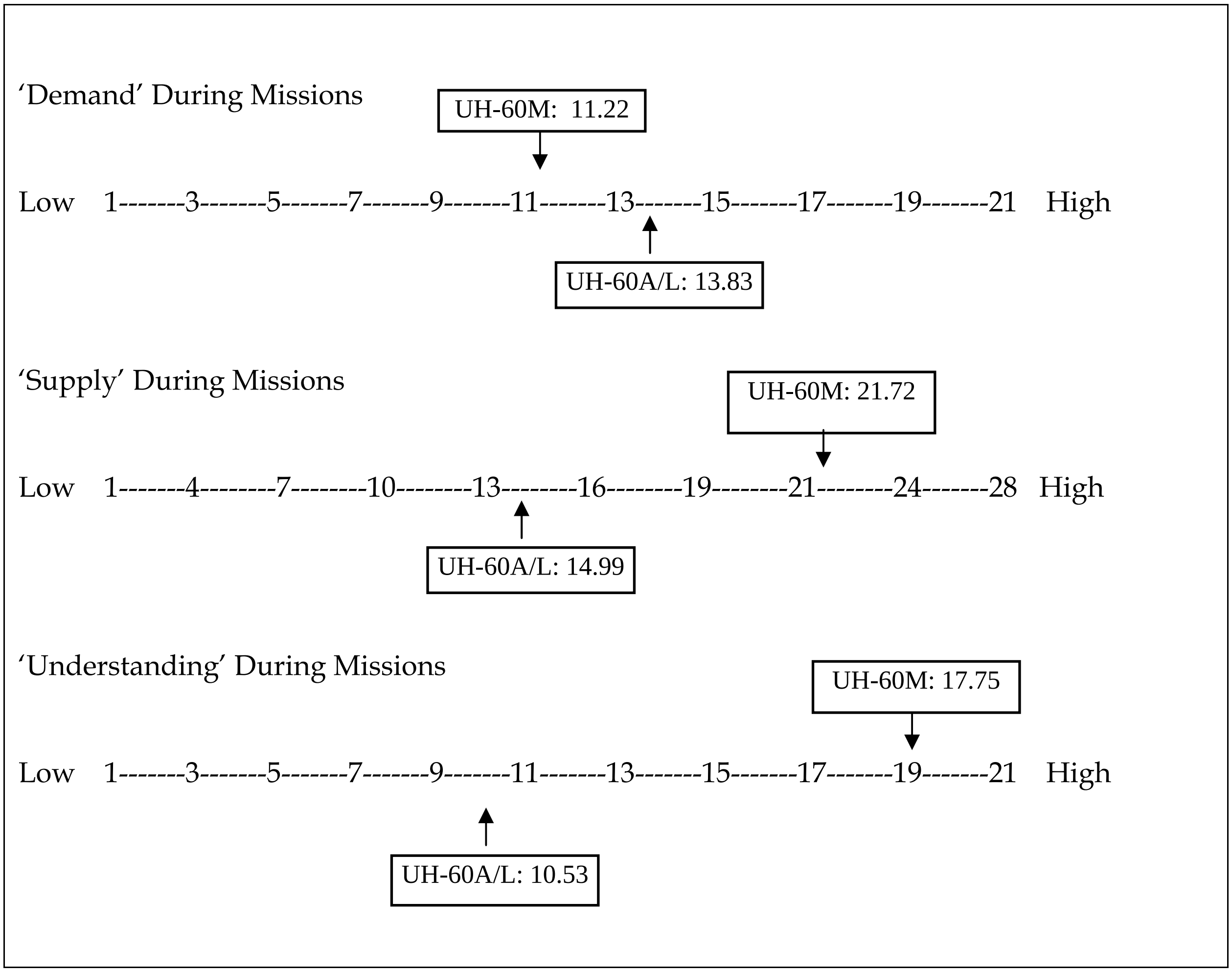

Figure 11. Comparison of subscale ratings for UH-60M versus UH-60A/L.

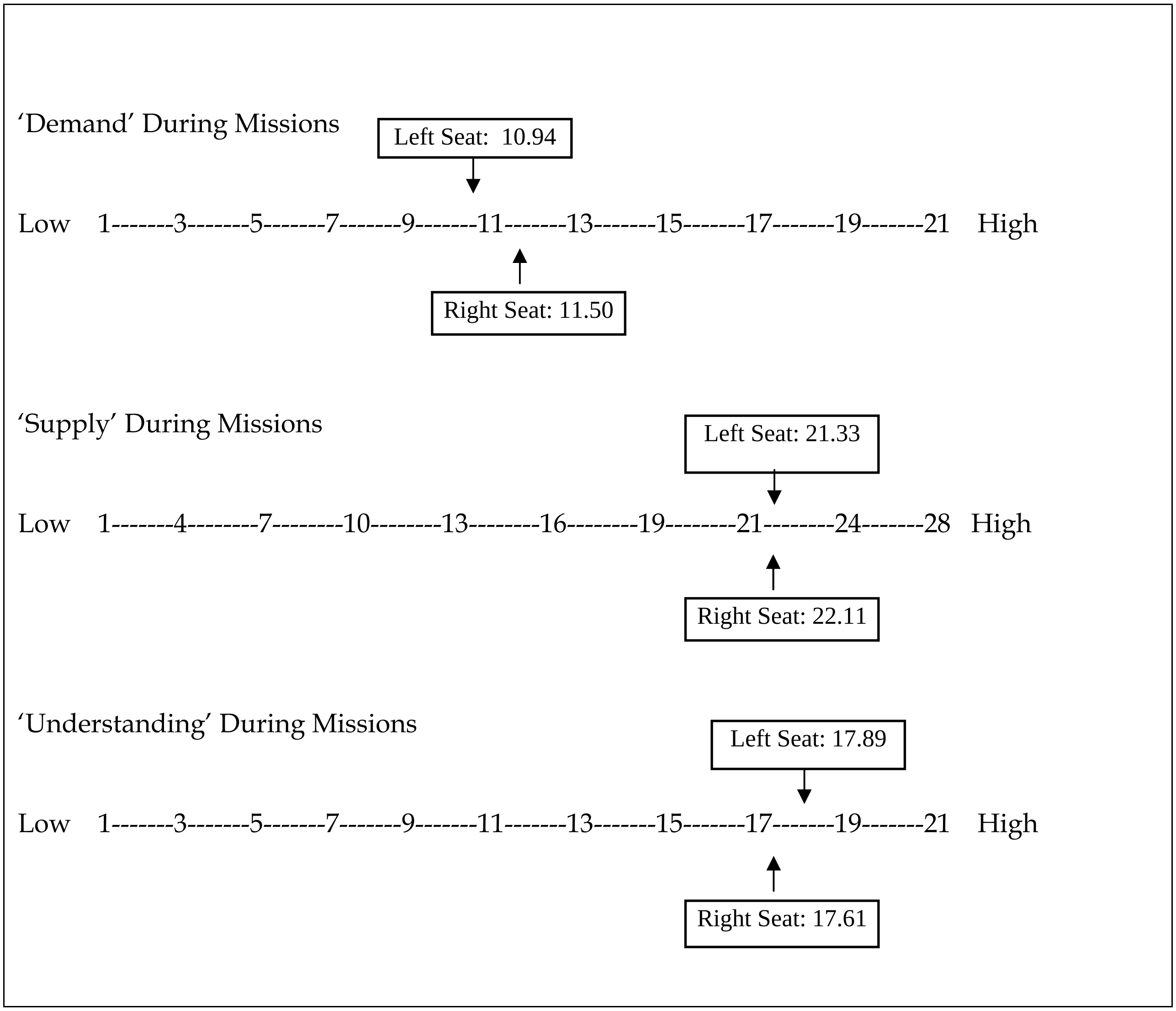

Figure 12. Comparison of subscale ratings for left versus right seat (UH-60M only).

3.2.2 TSC SA Ratings

The TSC provided an independent assessment of SA based on the scale shown in table 4. The mean TSC SA rating was 1.47. This indicates that the TSC perceived that the crews typically had adequate levels of SA with some periods of minor variation between perception and reality. A complete set of TSC comments regarding SA is given in appendix I.

Table 4. TSC SA ratings.

1	Crew was consistently aware of all entities on the battlefield.
2	Crew was aware of the battlefield with minor or insignificant variation between perception and reality.
3	Crew was aware of the battlefield. Variation between reality and perception did not significantly impact mission success.
4	SA needs improvement. Lack of SA had some negative effect on the success of the mission.
5	Lack of SA caused mission failure.

Mean Rating
1.47
(SD = 0.45)

3.3 PVI

The pilots completed a comprehensive PVI survey after each mission. This survey allowed the pilots to assign ratings for each question and provide comments about why they rated the question a certain way. This section of the report highlights the most common issues that were addressed by the pilots. A complete set of PVI results and pilot comments is included in appendix J.

3.3.1 Joint Variable Message Format (JVMF)

JVMF is a standard messaging format used in the UH-60M Black Hawk to exchange digital messages between aircraft and ground units. The use of JVMF messaging enhances pilot's SA by allowing critical information to be passed quickly without the pilot having to resort to conventional voice communication; however, it also requires that pilots manage incoming messages and create outgoing messages. Although JVMF messaging is a great asset to pilots, there are concerns with the workload required to effectively manage the large amount of data created by such a large flow of information.

The JVMF messaging was the subject of many pilot comments during the LUT. The most common issue regarding the JVMF messages was the current method used to notify pilots of incoming messages. Currently, the JVMF symbol on the MFD changes to inverse video to indicate that a message was received. Inverse video means the colors of the text and background become inverted. The pilots stated that this method was ineffective and difficult to detect. As a result, many messages were left unread until the pilots realized there was a message.

The pilots also commented on two workload-related JVMF issues. First, the pilots indicated that sending free-text messages was workload intensive and caused them to remain "heads down" for extended periods of time. The second issue was difficulty navigating. The pilots commented that there were too many pages associated with JVMF messaging. Several of the pilots recommended that the number of pages be reduced and the remaining pages be better organized.

Another issue the pilots identified was difficulty in using the backspace function on the FMS. The JVMF page on the FMS requires the use of the left arrow button to backspace. This method

is inconsistent with the design of other pages in the FMS. The pilots indicated that this caused confusion and increased their workload as a result.

3.3.2 Collective and Cyclic Flight Controls

The pilots were asked to identify problems with the usability of the collective and cyclic flight controls and switches. Two issues were identified. The first issue was that the frequency selection switch on the collective was not intuitive. The pilots indicated that this switch worked in a manner opposite from that expected. They recommended that the design of the switch be improved so when the switch is pushed “up,” the frequencies scroll “up” and vice versa. The second issue was hand interference with the cyclic mounted stabilator “slew-up” switch when pilots wore MOPP gloves.

3.4 Simulator Sickness

Pilots reported very few simulator sickness symptoms during the LUT. Most of the symptoms involved slight sweating, general discomfort, fatigue, and mild eyestrain, and headache. The overall mean total severity score (post mission) for the pilots was 7.49 (see table 5). The simulator sickness scores were also compared for left and right seat positions. The total severity scores for left and right seats were 5.58 and 9.33, respectively. These results show a large difference; however, the difference was not statistically significant (WSRT, z = -0.944, p = 0.345). Overall, the SIL posed no problems for simulator sickness and should continue to be very suitable as a simulation environment in the future.

Table 5. Simulator sickness questionnaire ratings.

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)	SD
Pre-Mission	1.59	1.06	1.95	1.67	4.09
Post Mission	6.36	8.64	2.71	7.49	6.12
Right seat	4.75	5.86	3.09	5.58	8.47
Left seat	7.93	11.36	2.32	9.33	7.41

SD = standard deviation

3.4.1 Comparison of SIL SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during the LUT were similar to or different from ratings obtained in other helicopter simulators, the mean total severity score for the SIL was compared to the mean total severity scores for several other helicopter simulators (see table 6): the AH-64A, S-3H, CH-46E, CH-56D, CH-56F, Sikorsky reconnaissance attack helicopter (RAH)-66 Engineering Development Simulator (EDS), RAH-66 Comanche portable cockpit (CPC), and the Battlefield Highly Immersive Virtual Environment (BHIVE). These simulators typically induced low to moderate levels of simulator sickness symptoms in pilots.

Table 6. Comparison of SIL SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A*	-----	-----	-----	25.81
SH-3H	14.70	20.00	12.40	18.80
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60 BHIVE (LEUE)	6.36	11.81	3.09	9.15
UH-60M BHIVE (EUD)	13.88	6.89	0	8.50
CH-53D	7.20	7.20	4.00	7.50
SIL	**6.36**	**8.64**	**2.71**	**7.49**
CH-46E	5.40	7.80	4.50	7.00

*SSQ subscale data not available.

3.5 Eye Tracker

The importance of collecting eye tracker data was to determine how well the design of the aircraft allowed the flying pilot to remain focused outside the aircraft during visual flight rules (VFR). Of secondary importance was the percentage of time the non-flying pilot spent focused outside the aircraft during VFR. Analyzing the eye tracker data to answer these questions was difficult because of the nature of this operational test. First, several different missions were flown that have an impact on eye tracker data. For example, VFR, instrument flight rules (IFR), single-ship, and multi-ship missions were flown during the LUT. We anticipated differences in the eye tracker data in each case, so we evaluated the eye tracker data collectively and separately. Another challenge was that the pilots were allowed to transfer the flight controls whenever necessary, as is the customary procedure in the UH-60 aircraft. In order to correctly analyze the eye tracker data, we had to know which pilot was flying at all times. We accomplished this by closely monitoring the test and creating new data segments every time the pilots transferred the controls. These segments were verified post mission by a review of the audio and video tapes of the missions.

Table 7 shows the percentage of time the flying and non-flying pilots spent fixated OTW. Notice that the OTW percentage is considerably larger for both the flying and non-flying pilots during multi-ship missions.

Table 7. OTW eye tracker results.

	All Missions	Single-Ship Missions	Multi-Ship Missions
Flying Pilot	85.60%	68.04%	90.12%
Non-Flying Pilot	28.21%	23.50%	32.96%

Figure 13 shows a graphical representation of the eye tracker data for the flying pilot, regardless of seat position. This figure shows the percentage of mission time that pilots were focused on each AOI. The data for the flying pilot were similar, regardless of seat position.

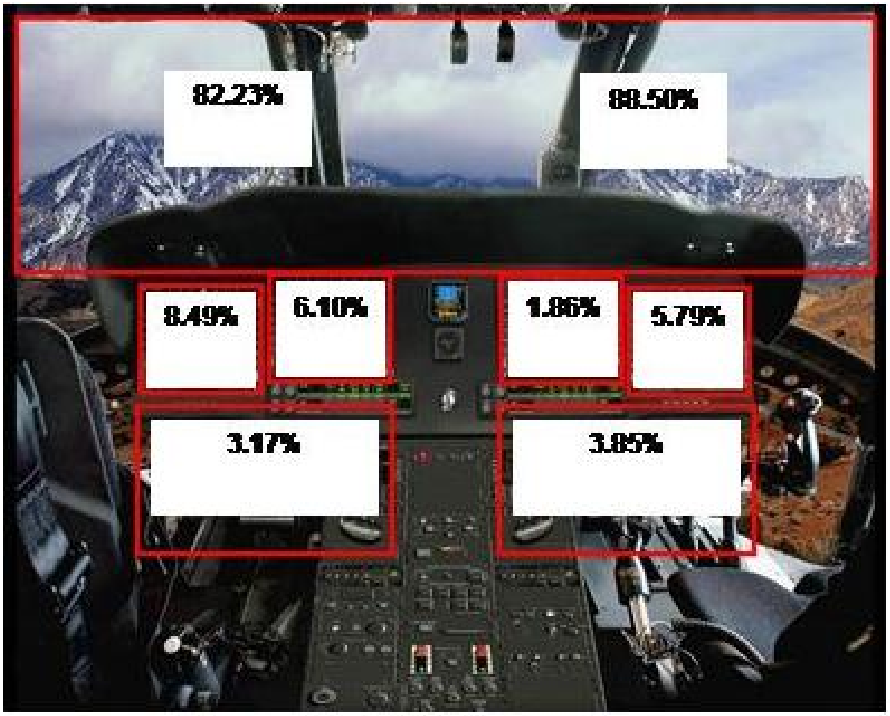

Figure 13. Graphical representation of eye tracker results (flying pilot).

Figure 14 shows a graphical representation of the eye tracker data for the non-flying pilot, regardless of seat position. This figure shows the percentage of mission time that pilots were focused on each AOI. The eye tracker data for the non-flying pilot seemed to differ significantly, depending on seat position.

A complete set of eye tracker data showing the results by seat position and mission type is presented in appendix K.

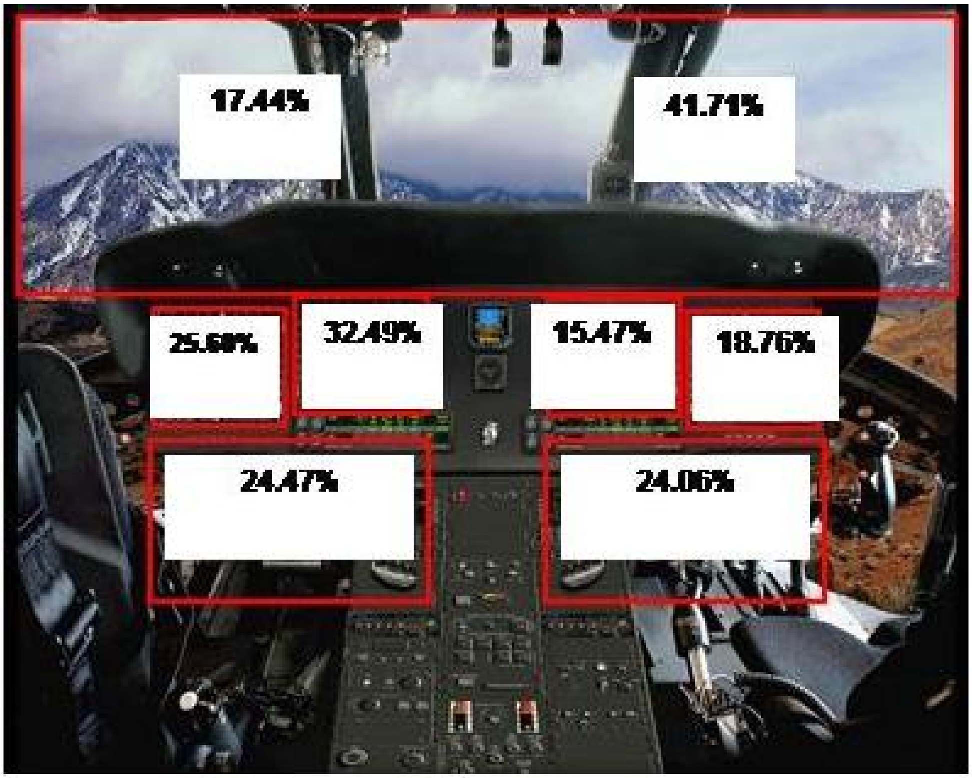

Figure 14. Graphical representation of eye tracker results (non-flying pilot).

3.5.1 Comparison of Eye Tracker Data From Previous UH-60 Assessments

The LUT was one of three evaluations conducted to evaluate the suitability of the UH-60M crew station. Eye tracker data were also collected during two other UH-60 evaluations, the Early User Demonstration 2 (EUD2) and the Limited Early User Evaluation (LEUE). Table 8 shows a comparison of eye tracker data from each of the three evaluations. Although a comparison of the results of each evaluation is useful, one must be cautious to remember that each set of data was collected in different evaluations that were all conducted differently. For example, the scenarios flown in each evaluation were different, the areas of interest were defined differently in each evaluation, and a different number of participants with different experience levels participated in each evaluation.

Table 8. Comparison of eye tracker results from EUD2, LUT, and LEUE.

	EUD2		**LUT**		**LEUE**	
	Flying Pilot	**Non-Flying Pilot**	**Flying Pilot**	**Non-Flying Pilot**	**Flying Pilot**	**Non-Flying Pilot**
Outside	69.21%	N/A	85.60%	28.21%	60.86%	26.30%
Inside	30.79%	N/A	14.40%	71.79%	39.14%	73.70%

4. Summary

4.1 Summary of Crew Workload

Pilots reported a mean workload rating of 2.71. This indicates that there was enough workload capacity for all desirable tasks.

Two tasks received peak workload ratings of greater than 6. A workload rating higher than 6 indicates that workload was not tolerable for the task. These tasks included maintaining airspace surveillance and transmitting tactical reports.

The TSC rated the average pilot workload at 2.91, indicating that the pilots had enough workload capacity for all desirable tasks.

Both pilot and TSC overall workload ratings during the LUT showed an improvement over the previous UH-60M assessment during EUD 2.

4.2 Summary of Crew Situational Awareness

Pilots reported a mean SA rating of 28.25 for the UH-60M—a significant increase compared to their SA rating of 11.69 for the UH-60A/L.

The SA ratings for the left and right seats were statistically insignificant.

Increased SA was attributed to the addition of the digital map system.

The tactical steering committee rated crew SA as 1.47. This indicates that the crew was aware of the battlefield and their own ship with minor or insignificant variation between perception and reality.

Both pilot and TSC overall SA ratings during the LUT showed an improvement over the previous UH-60M assessment during EUD 2.

4.3 PVI

The pilots indicated that the "inverse video" JVMF notification was difficult to detect. As a result, many messages were left unread until pilots realized there was a message.

The task of sending free-text messages was workload intensive and caused pilots to remain "heads down" for extended periods.

The pilots indicated that too many pages were associated with JVMF messaging, which caused difficulty in navigating the menu structure.

The pilots identified an inconsistency with the function of the backspace function on the FMS. The backspace function was associated with different keys on the FMS, depending on which page was being used.

The frequency select switch, located on the collective, was not intuitive.

The pilots experienced hand interference from the cyclic mounted stabilator slew-up switch when they wore MOPP gloves.

4.4 Simulator Sickness

Pilots reported mild simulator sickness symptoms after flying missions in the SIL. The total severity score was 7.49 with higher scores from the right seat.

Simulator sickness symptoms did not adversely affect pilot performance.

4.5 Eye Tracker

The flying pilot spent 85.60% of the time fixated OTW, 4.93% fixated on the left MFD, and 5.93% on the right MFD. The remaining time was spent looking at other areas that were not specifically examined during this evaluation (e.g., FMS, kneeboard, center console, etc.)

The non-flying pilot spent 28.21% fixated OTW, 21.11% on the left MFD, and 26.40% on the right MFD. The remaining time was spent looking at other areas that were not specifically examined during this evaluation (e.g., FMS, kneeboard, center console, etc.)

A large difference was noted between OTW percentages between single and multi-ship missions. The average flying pilot OTW percentage for single-ship missions was 68.04%, and the average flying pilot OTW percentage for multi-ship missions was 90.12%. This difference was attributed to the fact that pilots typically focus outside more during multi-ship missions to maintain their position relative to the aircraft in front of them.

The eye tracker results from the LUT showed an improvement in OTW percentages for the flying pilot compared to the previous UH-60M assessment during EUD 2.

5. Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the UH-60M as it continues its development:

Address and resolve the workload and PVI issues identified during the LUT.

Use the Crew Station Working Group, MANPRINT Working Group, and System Safety Working Group to track issues until satisfactorily resolved.

Continue to assess the crew station during future simulations and tests to evaluate pilot and system performance and assess new functionality that is integrated into the UH-60M design. Data from the workload, SA, and SSQ, plus the data from the eye tracker, should be collected again during future UH-60M crew station evaluations. This procedural continuity will allow direct comparison after further design and development of the UH-60M crew station to check for continued improvements in workload, SA, and PVI.

6. References

Crowley, J. S. Simulator sickness: A problem for army aviation. *Aviation Space and Environmental Medicine* **1987**, *58*, 355-357.

Endsley, M. R. Design and evaluation for situation awareness enhancement. *Proceedings of the Human Factors Society 32nd Annual Meeting* **1988**, *1,* 92-101.

Endsley, M. R. *Situation awareness analysis and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

Gordon, C. C.; Donelson, S. M. *1988 Anthropometric Survey of U.S. Army Personnel: Pilot Summary Statistics*; TR-91-040:Natick, MA, 1991.

Kennedy, R. S.; Lane, N. E.; Berbaum, K. S.; Lilienthal, M. G. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology* **1993**, *3,* 203-220.

Kennedy, R. S.; Lilienthal, M. G.; Berbaum, B. A.; Balzley, B. A.; McCauley, M. E. Simulator sickness in U.S. navy flight simulators. *Aviation Space and Environmental Medicine* **1989**, *60,* 10-16.

O'Brien, T. G.; Charlton, S. G. *Handbook of Human Factors Testing and Evaluation,* Lawrence Erlbaum Associates, Mahweh, New Jersey, 1996.

Roscoe, A. H. *The airline pilots view of flight deck workload: A preliminary study using a questionnaire.* Technical Memorandum No. FS (B) 465. Bedford, UK: Royal Aircraft Establishment. ADA116314, 1985.

Roscoe, A. H.; Ellis, G. A. *A Subjective Rating Scale For Assessing Pilot Workload in Flight: A Decade Of Practical Use*. Royal Aerospace Establishment, Bedford, UK, 1990.

Taylor, R. M. *Situational awareness rating technique (SART): The development of a tool for aircrew systems design*. Proceedings of the NATO Advisory Group on Aerospace Research and Development (AGARD) Symposium on Situational Awareness in Aerospace Operations. AGARD-CP-478, 3/1 - 3/17). Neuilly Sur Seine, France: NATO – AGARD, 1989.

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Appendix A. Bedford Workload Rating Scale

1. PIN __ __ __ __ __   2. Date (DD/MMM/YY): __ __/ __ __ __/ **0 4**

3. Mission ID number ________________________

4. Right Seat _______   Left Seat _______   (Check one)

Workload

5. Rate the workload for the Flight and Mission Tasks you performed ***in comparison to your experiences in the UH-60A/L***. Use the scale provided on the last page of this questionnaire. For example, if on Task 1026 (Perform Electronically Aided Navigation) you normally feel your workload would be a '5', indicate that in the column under UH-60A/L. With that in mind, make a workload judgment for Task 1026 in the UH-60M. Place the workload rating in the blank next to each Flight and Mission Task. If you did not perform a task during the mission that you just completed, place an X in the non-applicable (N/A) column.

Task No.	Flight and Mission Tasks	UH-60A/L Workload	UH-60M Workload	N/A
1014	Maintain Airspace Surveillance			
1016	Perform Hover Power Check			
1017	Perform Hovering Flight			
1018	Perform VMC Takeoff			
1023	Perform Fuel Management Procedures			
1025	Navigate by Pilotage and Dead Reckoning			
1026	Perform Electronically Aided Navigation			
1028	Perform VMC Approach			
1029	Perform a Roll-on Landing			
1068	Perform Emergency Procedures			
1076	Perform Radio Navigation			
1077	Perform Holding Procedures			
1079	Perform Radio Communication Procedures			
1081	Perform Nonprecision Approach			
1082	Perform Precision Approach			
1083	Perform Inadvertent IMC Procedures			
1084	Perform Command Instrument System Operations			
1095	Operate Aircraft Survivability Equipment			
1135	Perform Instrument Maneuvers			
1136	Perform Go-Around			
1146	Perform VMC Flight Maneuvers			
1150	Select Landing Zone/Pickup Zone			
2008	Perform Evasive Maneuvers			
2009	Perform Multi-Aircraft Operations			

Task No.	Flight and Mission Tasks (cont'd)	UH-60A/L Workload	UH-60M Workload	N/A
2044	Perform Actions on Contact			
2078	Perform Terrain Flight Mission Planning			
2079	Perform Terrain Flight Navigation			
2081	Perform Terrain Flight			
2083	Negotiate Wire Obstacles			
2086	Perform Masking and Unmasking			
2090	Perform Tactical Communication Procedures			
2091	Transmit Tactical Reports			

If you gave a workload rating of '6' or higher for any task on the UH-60M only, explain why the workload was high for the task.

____

____

____

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____

In the mission you just flew, list any flight and/or mission tasks on the UH-60M that you had to ask your crewmember to accomplish because your workload was too high:

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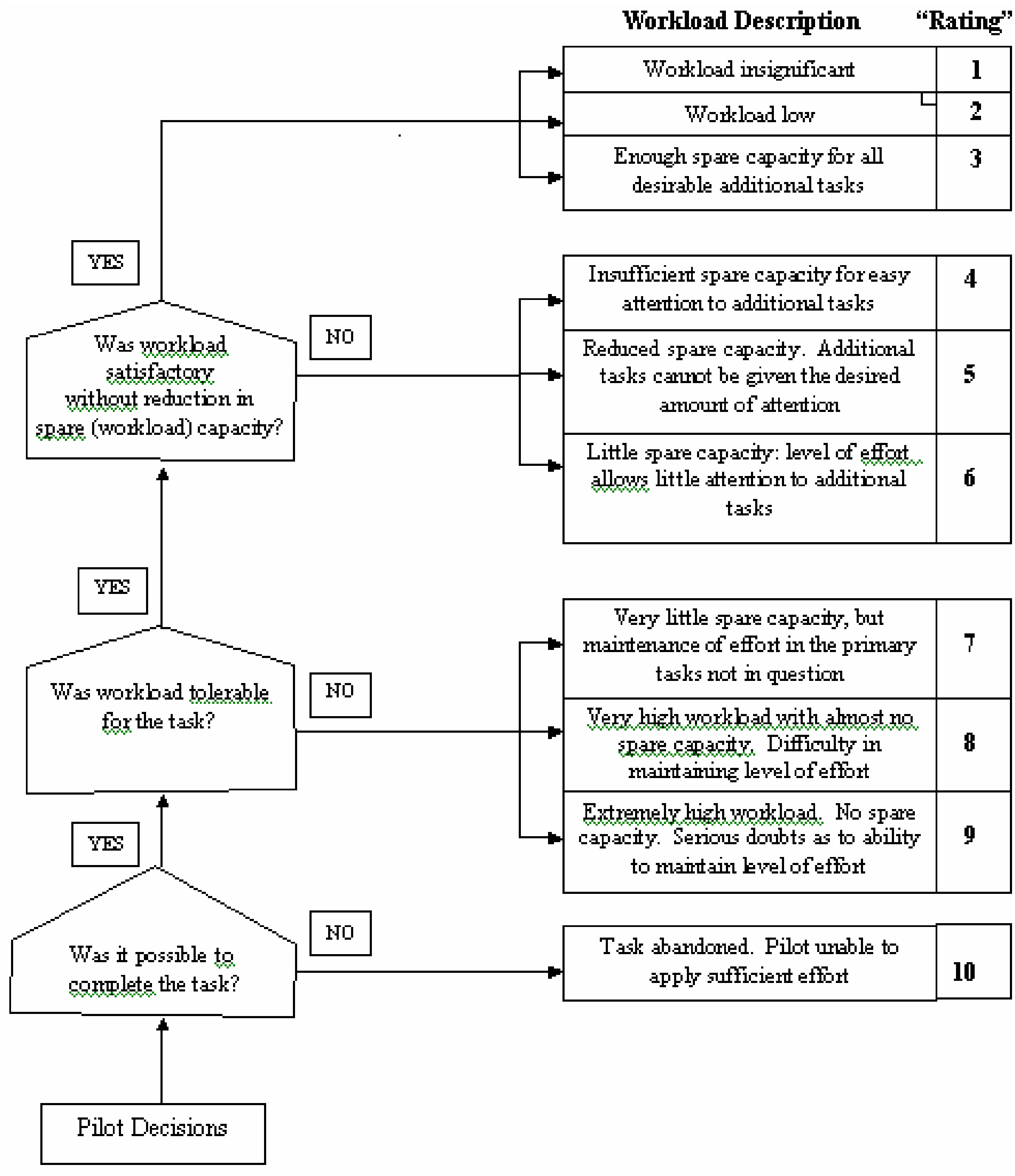

Workload Description
"Rating"
Workload insignificant
1
Workload low
2
Enough spare capacity for all desirable additional tasks
3
Insufficient spare capacity for easy attention to additional tasks
4
Reduced spare capacity. Additional tasks cannot be given the desired amount of attention
5
Little spare capacity: level of effort allows little attention to additional tasks
6
Very little spare capacity, but maintenance of effort in the primary tasks not in question
7
Very high workload with almost no spare capacity. Difficulty in maintaining level of effort
8
Extremely high workload. No spare capacity. Serious doubts as to ability to maintain level of effort
9
Task abandoned. Pilot unable to apply sufficient effort
10
YES
NO
Was workload satisfactory without reduction in spare (workload) capacity?
YES
NO
Was workload tolerable for the task?
YES
NO
Was it possible to complete the task?
Pilot Decisions

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Appendix B. Situational Awareness Rating Technique

Pin # __ __ __ __ __ Date (DD/MM/YY): __ __/__ __ __/ **04**

Mission ID Number: ____________________

Right Seat _______ Left Seat _______ (Check one)

Situation Awareness

SA1. Situation Awareness is defined as “timely knowledge of what is happening as you perform your right or left seat tasks during the mission.”

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly.
Variability of Situation	Number of variables which require your attention
Complexity of Situation	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity; ability to anticipate and keep up with the flow of events
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events
Division of Attention	Ability to divide your attention among several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

Assuming you had just performed this mission in a UH-60A/L, rate the level of each component of situation awareness that you had. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Variability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Complexity of situation:	Low	1---------2---------3---------4---------5---------6---------7	High

SUPPLY

Arousal:	Low	1---------2---------3---------4---------5---------6---------7	High
Spare mental capacity:	Low	1---------2---------3---------4---------5---------6---------7	High
Concentration:	Low	1---------2---------3---------4---------5---------6---------7	High
Division of attention:	Low	1---------2---------3---------4---------5---------6---------7	High

UNDERSTANDING

Information quantity:	Low	1---------2---------3---------4---------5---------6---------7	High
Information quality:	Low	1---------2---------3---------4---------5---------6---------7	High
Familiarity:	Low	1---------2---------3---------4---------5---------6---------7	High

For the mission that you just completed *in the UH-60M*, rate the level of each component of situation awareness that you had. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation: Low 1---------2---------3---------4---------5---------6---------7 High

Variability of situation: Low 1---------2---------3---------4---------5---------6---------7 High

Complexity of situation: Low 1---------2---------3---------4---------5---------6---------7 High

SUPPLY

Arousal: Low 1---------2---------3---------4---------5---------6---------7 High

Spare mental capacity: Low 1---------2---------3---------4---------5---------6---------7 High

Concentration: Low 1---------2---------3---------4---------5---------6---------7 High

Division of attention: Low 1---------2---------3---------4---------5---------6---------7 High

UNDERSTANDING

Information quantity: Low 1---------2---------3---------4---------5---------6---------7 High

Information quality: Low 1---------2---------3---------4---------5---------6---------7 High

Familiarity: Low 1---------2---------3---------4---------5---------6---------7 High

SA2. Rate the level of situational awareness you had for each of the battlefield elements during the mission by placing and X in the appropriate column for each battlefield element. Keep in mind that the simulation facility may be limited in its ability to display some of these elements; in the case, please place 'N/A' somewhere in the row for that battlefield element.

Battlefield Elements	Very High Level of Situation Awareness	Fairly High Level of Situation Awareness	Intermediate Level of Situation Awareness	Fairly Low Level of Situation Awareness	Very Low Level of Situation Awareness
Location of Enemy Units					
Location of Friendly Units					
Location of Non-Combatants (e.g., Civilians)					
Location of My Aircraft During Mission					
Location of Other Aircraft Related to the Mission					
Location of Cultural Features (e.g., bridges)					
Route Information (ACPs, BPs, EAs, RPs, etc.)					
Status of My Aircraft Systems (e.g., fuel consumption)					

Describe any instances when you feel you had low situational awareness during the mission:

____

____

____

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Appendix C. PVI Questionnaire

1. PIN __ __ __ __ __   2. Date (DD/MMM/YY): __ __ / __ __ __ / **0 4**

3. Mission ID number ___________________________

4. Right Seat _______   Left Seat _______   (Check one)

The purpose of this questionnaire is to identify any problems that you experienced when using the various crew station components to perform your mission tasks. Your responses should be based only on the problems that you experienced during the mission that you just completed.

PV1. The following table lists the functional components (and some sub-components) of the UH-60M crew station. For each functional component (and sub-component), indicate whether or not you experience a problem using the component in a quick and efficient manner during the mission you just completed. Check “Yes” if you experience one or more problems. Check “No” if you did not experience any problems. Check “Not Used” if you did not use the functional component during the mission you just completed.

- Multifunction Displays (MFD) Yes ______ No ______ Not Used ________
    - Primary Flight Display (PFD) Yes ______ No ______ Not Used ________
    - Navigation Display (ND) Yes ______ No ______ Not Used ________
    - Engine Instrument Caution Advisory System (EICAS) Yes ______ No ______ Not Used ________
    - Digital Map System (DMS) Yes ______ No ______ Not Used ________
    - Joint Variable Message Format (JVMF) Yes ______ No ______ Not Used ________
- Flight Management System (FMS) Yes ______ No ______ Not Used ________
    - JVMF Entry Yes ______ No ______ Not Used ________
    - GPS / Flight Plan Yes ______ No ______ Not Used ________
    - Voice Communications Yes ______ No ______ Not Used ________
    - Radio Navigation Yes ______ No ______ Not Used ________
- Multifunction Slew Controller (MFSC) Yes ______ No ______ Not Used ________

- Flight Director Display Control Panel (FDDCP) Yes ______ No ______ Not Used ________

If you answered “Yes” to any of the questions, please describe a) the problems you experienced, b) how much the problems degraded your performance, and c) any recommendation you have for improving the design of the various functional components.

PV2. On average, how quickly were you able to navigate through menu screens on the:

Primary Flight / Navigation Displays (PFD/ND) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Digital Map System (DMS) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Flight Management System (FMS) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Engine Instrument Caution Advisory System (EICAS) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Joint Variable Message Format (JVMF)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

If you answered "Borderline", "Somewhat Slowly", or "Very Slowly" to any of the questions, list the component and why navigation was slow (e.g., 'navigating the menu system on the FMS was a slow process due to having to page through several screen displays').

____

PV3. How often did you forget the steps required for navigating through the menu screens to accomplish a task?

Primary Flight / Navigation Displays (PFD/ND) (Circle one)

1	2	3	4
Never	Seldom	Frequently	Always

Digital Map System (DMS) (Circle one)

1	2	3	4
Never	Seldom	Frequently	Always

Flight Management System (FMS) (Circle one)

1	2	3	4
Never	Seldom	Frequently	Always

Engine Instrument Caution Advisory System (EICAS) (Circle one)

1	2	3	4
Never	Seldom	Frequently	Always

Joint Variable Message Format (JVMF)

1	2	3	4
Never	Seldom	Frequently	Always

If you answered “Frequently” or “Always” to any of the questions, list the component and the tasks for which you forgot how to navigate through the menu screens (e.g., “I often forgot the steps for navigating through the menu screens on the FMS to change frequencies on the UHF radio”).

PV4. Please rate the intuitiveness of the following aspects of the Multifunction Switch Controller (MFSC) (a.k.a. potato grip):

PV4-1. When you actuated the directional control, did the cursor move in the direction you expected?

1	2	3	4	5
Very Intuitive	Somewhat Intuitive	Neither Intuitive nor Confusing	Somewhat Confusing	Very Confusing

PV4-2. When you actuated one of the three switches, did the expected action occur on the MFD?

1	2	3	4	5
Very Intuitive	Somewhat Intuitive	Neither Intuitive nor Confusing	Somewhat Confusing	Very Confusing

If you answered "Neither Intuitive nor Confusing", "Somewhat Confusing", or "Very Confusing", please describe any problem with either the cursor control or switches, exactly what you were trying to accomplish on the MFD, and what actually happened on the MFD.

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PV5. Did you have any difficulty using any of the switches on the collective or the cyclic grips?

Collective Grip	Yes ________	No _________
Cyclic Grip	Yes ________	No _________

If you answered "Yes" for either flight control, please list which flight control and switch(es), and the problems you experienced (e.g., confuses two switches due to similar shape, switch too hard to reach).

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PV6. Was there any symbology depicted on the following displays/pages that was difficult to quickly and easily understand?

Primary Flight Displays (PFD)	Yes ________	No _________
Navigation Displays (ND)	Yes ________	No _________
EICAS	Yes ________	No _________
Digital Map System (DMS)	Yes ________	No _________
Aircraft Survivability Equip (ASE)	Yes ________	No _________

If you answered "Yes" to any of the questions, please describe a) the display/page, b) the symbology that was difficult understand, c) how the symbology may have degraded your performance, and d) any recommendation you have for improving the design of the various functional components.

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PV7. Did you experience any problems with symbology cluttter on the following displays that made it difficult to understand all the elements of information available to you?

PFD – Full	Yes ________	No _________
PFD – Arc	Yes ________	No _________
PFD – Hover	Yes ________	No _________
ND – Full	Yes ________	No _________
ND – Plan	Yes ________	No _________
Digital Map	Yes ________	No _________

If you answered "Yes" for any of these displays, please indicate which display and what symbols were cluttering the display to make it difficult to understand. Please include any recommendation you might have to alleviate the difficulty.

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PV8. Did you experience any sort of hand discomfort while using the MSFC, collective, or cyclic grips?

MFSC	Yes ________	No _________
Collective	Yes ________	No _________
Cyclic	Yes ________	No _________

If you answered "Yes" for any of these controls, please list which control became uncomfortable, a rough description of how your hand was uncomfortable, what tasks you were trying to accomplish, and approximately how long it took for your hand to become uncomfortable.

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PV9. For the JVMF reports that you sent, how would you rate the ease/difficulty of sending the following reports:

Position Report

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Free Text Message

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered "Borderline", "Somewhat Difficult", or "Very Difficult", please indicate which type of message you sent, the exact difficulties you encountered, and any recommendations to alleviate the problem.

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PV10. How would you rate your ability to detect the following occurrences based on the characteristics of the flight displays?

JVMF Message (MFD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Caution / Advisory (MFD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Warning (Master Warning Panel)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Entry into Operational Limits (per Chp 5) on the Power Pod

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered “Borderline”, “Somewhat Difficult”, or “Very Difficult”, please indicate which annunciation you had difficulty detecting, why you may have had difficulty detecting it, and any recommendations to make the annunciation more noticeable or salient.

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Appendix D. Simulator Sickness Questionnaire

1. PIN #: __ __ __ __ __   2. Date (DD/MMM/YY): __ __ - __ __ __ - **04**

3. Mission ID Number: ________

4. Seat you will fly from: Right Seat _______ Left Seat _______ (Check one)

5. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
a. General discomfort	None	Slight	Moderate	Severe
b. Fatigue	None	Slight	Moderate	Severe
c. Headache	None	Slight	Moderate	Severe
d. Eyestrain	None	Slight	Moderate	Severe
e. Difficulty focusing	None	Slight	Moderate	Severe
f. Increased salivation	None	Slight	Moderate	Severe
g. Sweating	None	Slight	Moderate	Severe
h. Nausea	None	Slight	Moderate	Severe
i. Difficulty concentrating	None	Slight	Moderate	Severe
j. Fullness of head	None	Slight	Moderate	Severe
k. Blurred vision	None	Slight	Moderate	Severe
l. Dizzy (eyes open)	None	Slight	Moderate	Severe
m. Dizzy (eyes closed)	None	Slight	Moderate	Severe
n. Vertigo*	None	Slight	Moderate	Severe
o. Stomach awareness**	None	Slight	Moderate	Severe
p. Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.
** Stomach awareness is a feeling of discomfort just short of nausea.

6. Are you in your usual state of health and fitness? **YES** **NO**

7a. Have you been ill in the past week? **YES** **NO**
 b. If yes, are you fully recovered? **YES** **NO** **N/A**

1. PIN #: __ __ __ __ __   2. Date (DD/MMM/YY): __ __ - __ __ __ - **04**

3. Mission ID Number: ____________________________________

4. Seat you flew from: Right Seat _______ Left Seat _______ (Check one)

5. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
a. General discomfort	None	Slight	Moderate	Severe
b. Fatigue	None	Slight	Moderate	Severe
c. Headache	None	Slight	Moderate	Severe
d. Eyestrain	None	Slight	Moderate	Severe
e. Difficulty focusing	None	Slight	Moderate	Severe
f. Increased salivation	None	Slight	Moderate	Severe
g. Sweating	None	Slight	Moderate	Severe
h. Nausea	None	Slight	Moderate	Severe
i. Difficulty concentrating	None	Slight	Moderate	Severe
j. Fullness of head	None	Slight	Moderate	Severe
k. Blurred vision	None	Slight	Moderate	Severe
l. Dizzy (eyes open)	None	Slight	Moderate	Severe
m. Dizzy (eyes closed)	None	Slight	Moderate	Severe
n. Vertigo*	None	Slight	Moderate	Severe
o. Stomach awareness**	None	Slight	Moderate	Severe
p. Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.

** Stomach awareness is a feeling of discomfort just short of nausea.

Appendix E. TSC Survey

Pin: ________________

Mission Trial _______________   Date (DD/MMM/YY): __ __ / __ __ __ / 0 4

TSCWL1. Place the workload rating in the blank next to each crewmember using the rating scale on the next page.

Crew Members	Overall Workload Rating For This Mission
Left Seat	
Right Seat	

If you assigned a workload rating of '6' or higher for either crewmember, explain why:

____

____

____

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TSCWL2. Rate the effectiveness of aircrew coordination as defined by the USAAVNC Aircrew Coordination ETP and TC 1-210.

1	2	3	4	5
Excellent	Good	Average	Needs Improvement	Unacceptable

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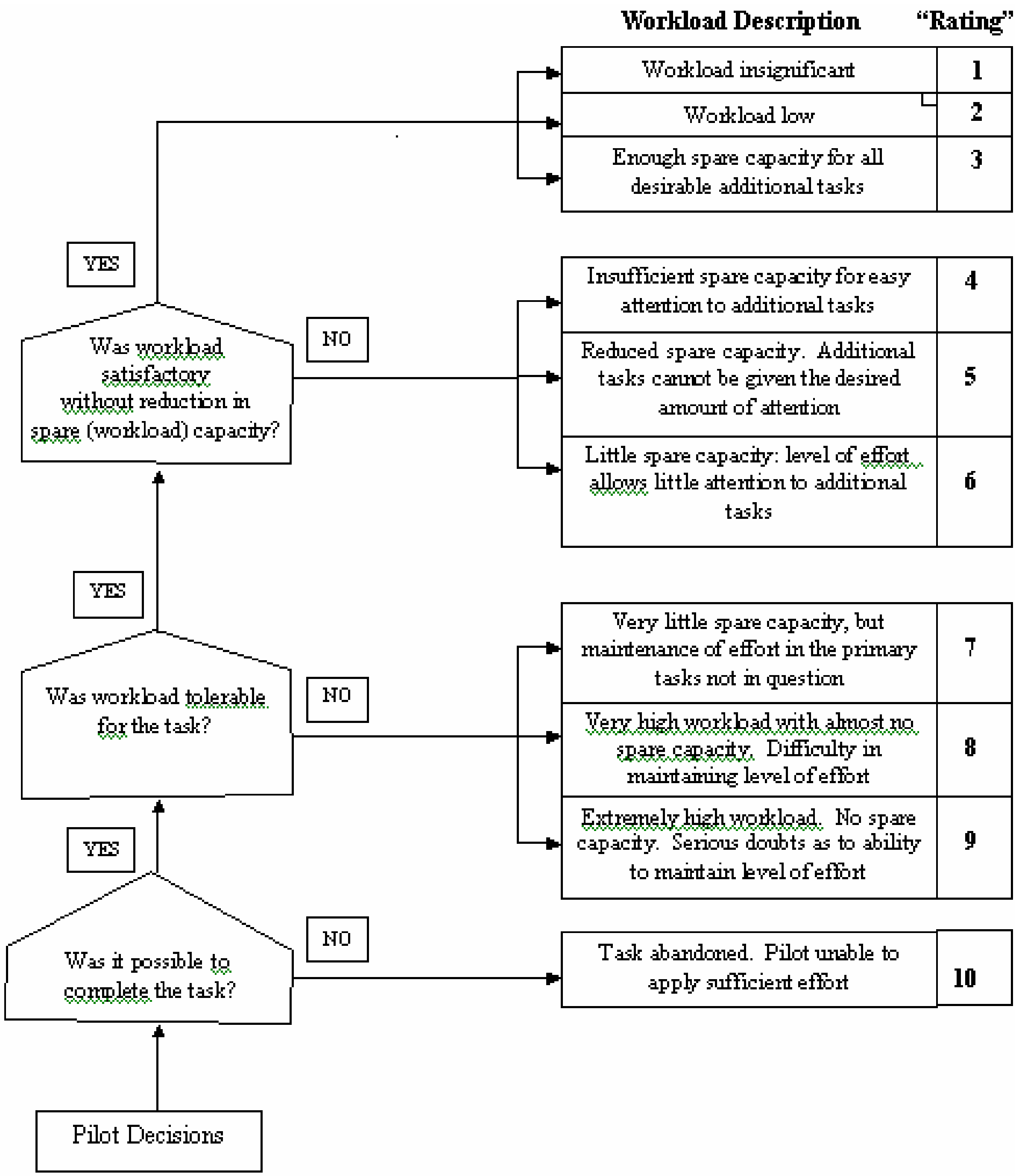

Workload Description
"Rating"
Workload insignificant
1
Workload low
2
Enough spare capacity for all desirable additional tasks
3
Insufficient spare capacity for easy attention to additional tasks
4
Reduced spare capacity. Additional tasks cannot be given the desired amount of attention
5
Little spare capacity: level of effort allows little attention to additional tasks
6
Very little spare capacity, but maintenance of effort in the primary tasks not in question
7
Very high workload with almost no spare capacity. Difficulty in maintaining level of effort
8
Extremely high workload. No spare capacity. Serious doubts as to ability to maintain level of effort
9
Task abandoned. Pilot unable to apply sufficient effort
10
YES
Was workload satisfactory without reduction in spare (workload) capacity?
NO
YES
Was workload tolerable for the task?
NO
YES
Was it possible to complete the task?
NO
Pilot Decisions

PIN __ __ __ __ __ Date (DD/MMM/YY): __ __ / __ __ __ / **0 4**

Mission ID number ___________________________

TSC SITUATION AWARENESS RATING SCALE

	Check one
Crew was consistently aware of all entities on the battlefield as well as the status of their aircraft	
Crew was aware of the battlefield and their own ship with minor or insignificant variation between perception and reality.	
Crew was aware of the battlefield and their own ship. Variation between reality and perception did not significantly impact mission success.	
SA needs improvement. Lack of SA had some negative effect on the success of the mission.	
Lack of SA caused mission failure.	

Describe any problems that aircrews had with situation awareness.

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PIN __ __ __ __ __ Date (DD/MMM/YY): __ __ / __ __ __ / **0 4**

Mission ID number ___________________________

TSC MISSION SUCCESS QUESTIONNAIRE

TSC MS1. Did the UH-60M crew complete their mission objectives?

Yes _____ No _____

If no, why weren't the mission objectives completed?

____

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TSC MS2. Was the mission successful?

Yes _____ No _____

If no, what caused the mission to fail?

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Appendix F. Mean Workload Ratings for All ATM Tasks

Mean Workload Ratings for All ATM Tasks								
Task No.	**Task Description**	**101**	**105**	**140**	**192**	**213**	**645**	**Average**
1014	Mantain Airspace Surveillance	1.83	4.00	3.00	3.00	2.50	1.83	2.69
1016	Perform Hover Power Check	1.83	2.83	3.00	4.00	2.33	1.67	2.61
1017	Perform Hovering Flight	1.83	2.67	2.83	4.40	2.17	1.67	2.59
1018	Perform VMC Takeoff	1.83	3.33	3.00	4.80	2.50	1.67	2.86
1023	Perform Fuel Management Procedures	2.00	3.17	3.00	4.80	2.17	2.00	2.86
1025	Navigate by Pilotage and Dead Reckoning	1.83	1.75	2.00	3.00	2.17	2.00	2.13
1026	Perform Electronically Aided Navigation	1.67	2.33	2.00	3.75	2.17	1.83	2.29
1028	Perform VMC Approach	1.83	2.83	3.00	5.20	2.50	2.00	2.89
1029	Perform a Roll-on Landing	1.67	2.75	3.00	5.00	3.00	2.33	2.96
1068	Perform Emergency Procedures	1.75	3.40	3.00	4.67	2.67	2.00	2.91
1076	Perform Radio Navigation	1.50	2.50	3.00	4.00	2.00	-	2.60
1077	Perform Holding Procedures	1.50	2.50	3.00	5.50	-	2.00	2.90
1079	Perform Radio Communication Procedures	1.83	3.00	3.00	5.20	2.17	-	3.04
1081	Perform Nonprecision Approach	1.00	1.00	3.00	-	2.00	1.50	1.70
1082	Perform Precision Approach	1.50	2.50	3.00	4.00	2.00	3.50	2.75
1083	Perform Inadvertent IMC Procedures	2.00	3.00	3.50	5.00	3.50	-	3.40
1084	Perform Command Instrument System Operations	1.00	2.00	-	5.00	3.00	-	2.75
1095	Operate Aircraft Survivability Equipment	1.00	-	-	5.00	2.00	2.50	2.63
1135	Perform Instrument Maneuvers	1.50	2.50	3.00	5.00	2.50	-	2.90
1136	Perform Go-Around	1.50	1.00	-	-	-	2.00	1.50
1146	Perform VMC Flight Maneuvers	1.67	2.83	3.00	5.20	2.67	2.00	2.89
1150	Select Landing Zone/Pickup Zone	1.83	3.17	2.75	4.00	2.33	2.00	2.68
2008	Perform Evasive Maneuvers	1.50	1.00	3.00	5.33	2.50	2.00	2.56
2009	Perform Multi-Aircraft Operations	2.67	3.00	3.00	5.25	2.67	2.00	3.10
2044	Perform Actions on Contact	2.00	1.00	3.00	5.00	2.00	-	2.60
2078	Perform Terrain Flight Mission Planning	3.00	3.33	2.67	-	2.60	2.17	2.75
2079	Perform Terrain Flight Navigation	1.50	3.00	2.20	3.40	2.17	2.00	2.38
2081	Perform Terrain Flight	1.83	3.33	2.67	4.40	2.50	2.00	2.79
2083	Negotiate Wire Obstacles	1.83	3.00	2.80	5.25	2.33	-	3.04
2086	Perform Masking and Unmasking	-	1.00	3.00	4.00	-	2.20	2.55
2090	Perform Tactical Communication Procedures	2.60	3.50	3.00	5.20	2.60	2.00	3.15
2091	Transmit Tactical Reports	2.60	3.83	3.20	4.67	2.50	-	3.36

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Appendix G. Pilot Workload Comments

Task (1014)

- JVMF messaging. Checking aircraft systems. Fuel Checks.
- One pilot would be responsible for radios and navigation. The other pilot would fly the aircraft.
- Pilot on the controls stays outside when VMC, inside when IMC. Pilot not on the controls announced when inside more than 2-3 seconds when VMC, and scanned instruments when IMC. If pilot came off instrument scan more than 2-3 seconds during IMC the pilot announced it.

Task (1016)

- One pilot would fly the other would check the systems.
- Pilot on the controls announced when stable at desired hover height. Pilot announced hover torque, compared it to predicted and go or no-go torque's.

Task (1017)

- One pilot would fly the other would check systems and drift.
- Pilot on the controls remains focused outside during task.

Task (1018)

- One pilot would fly the other would monitor the systems.

Task (1023)

- Pilot on the controls stays outside. Pilot not on the controls notes numbers and calculates numbers.
- One pilot would fly the other would monitor systems.

Task (1025)

- One pilot would fly the other would monitor systems.
- Pilot on the controls inboard MFD was up digital map for scan purposes. Pilot inboard MFD was switched as needed by the mission.

Task (1026)

- As long as data and flight plans were loaded. Pilot entry would have required longer run up.
- One pilot would fly the other would monitor systems.

Task (1028)

- Pilot on the controls remained outside during task, pilot not on the controls helped as required.
- One pilot would fly the other would monitor systems.

Task (1076)

- One pilot would fly the other would monitor systems.

Task (1079)

- Pilot handled all radios. Pilot on the controls flew the aircraft.
- One pilot would fly the other would monitor systems.

Task (1081)

- Pilot on the controls flew the aircraft. Pilot not on the controls stayed ahead of aircraft as much as possible, performing radio communications and tuning navigation aids.
- One pilot would fly the other would monitor systems.

Task (1082)

- One pilot would fly the other would monitor systems.
- Pilot on the controls flew aircraft. Pilot not on the controls helped and prompted control inputs while scanning, announced descending through altitudes for arrival at FARP.

Task (1083)

- One pilot would fly the other would monitor systems.
- Pilot on the controls initiated IIMC procedure, flew aircraft. Pilot not on the controls backed up instrument scan for first 2 minutes then squawked EMER and made radio calls, tuned VOR and gave course guidance to pilot on the controls to proceed direct to the VOR.
- Performing inadvertent IMC procedures is difficult, but using the D-map I knew where I was.
- IIMC is a high workload activity regardless of aircraft.

Task (1135)

- One pilot would fly the other would monitor systems.
- Once the controls are coupled in the real aircraft, it will be easier.

Task (1146)

- One pilot would fly the other would monitor systems.

Task (2009)

- A Multi ship operation is a high workload environment and there is no difference between the two.

Task (2079)

- Under NVG, this is the single most taxing task we perform in current aircraft. In this cockpit, the map display makes this an easy and non-thinking task.

Task (2081)

- Pilot on the controls scanned outside. Pilot not on the controls stayed outside, task permitting. Low bug audio on radar ALT enhanced situation awareness greatly.

Task (2091)

- Sending messages.
- Sending tactical reports involves a lot of the pilot's attention.
- It still takes too much time to send JVMF messages.

If you gave a workload rating of 6 or higher for any task on the UH-60M only, explain why the workload was high for the task.

- JVMF- Too many things to do, too much time inside the cockpit. The pilots' head is down to send/receive/setup/change nets.

In the mission you just flew, list any flight and/or mission tasks on the UH-60M that you had to ask your crewmember to accomplish because your workload was too high.

- Call – ATC, Mission change engage a change to route.
- Time line information
- Trouble shooting my MFD/FMS, but only due to my lack of experience with a malfunctioning MFDs.
- Make some radio calls because I was busy with JVMF.
- Heading, lighting changes.
- Monitor torque during IIMC.

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Appendix H. Pilot SA Comments

Pilot Situation Awareness Comments

- When doing JVMF the pilot is inside and only one pilot is outside. The pilot inside is looking at entering /net and all the other requirements associated with JVMF. “Space” on entry keypad is too close, spend time hunting for key’s on the keyboard.
- Pilot workload is great. Change of mission caught my attention. Having to reset flight plan.
- Aircraft is hot with the glass cockpit. Needs better ventilation.
- PPC that is shown on display.
- JVMF messaging is very tasking compared to the rest of the aircraft.
- Trying to plot threat on D-Map as waypoint.
- When looking at the route, I needed to look at the information of other legs on the route.
- Getting information on threat reported. During the time it took to store it in the FMS and locate it on the Digital Map.
- IIMC as flight S/A of where other aircraft were.
- When the #2 FMS locked up, I didn’t know where I was.

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Appendix I. TSC Comments

TSC MS1 Comments:

- The mission objectives were completed, however the JVMF time synchronization made it more difficult to complete the mission. For unknown reason there is a miscompare between the XMIT status and GPS time which causes the JVMF to fail.
- Went into dive in IIMC and crashed aircraft. FMS #2 failure contributed significantly to the crash.
- The crew was unable to maintain aircraft control while transitioning to IIMC. Pilot workload was high partly due to excessive power and pitch changes resulting in zero airspeed and nose down descent.
- Erroneous information contributed to crew confusion while trying to maintain aircraft control while IIMC. FMS failure caused the pilot not on the controls to be unable to provide the pilot on the controls with helpful information to aid in aircraft recovery from an unusual attitude.

TSC MS2 Comments:

- Aborted had to replace, no IFM.
- Unusual attitude trying to avoid terrain. Both pilots confused about what information was actually correct.

TSCWL1 Comments:

- Even large differences in level of proficiency between pilot and copilot workload was manageable.
- Could not keep ahead of aircraft and mission tasks.
- Workload was adequately divided between the two aviators.
- During the mission change the pilot not on the controls was required to communicate with the flight, change the flight plan and talk voice with A2C2S. The aviator was slow to prioritize mission task. As a result of the task overload, the initial course to the waypoint was vague. Eventually the pilot not on the controls requested assistance from the pilot on the controls.
- With improved proficiency aviators are challenged less by the demands of the cockpit.
- The crew was able to successfully plot the intel on the threat in flight. The time required to plot the threat lead the crew right over the threat before they discovered the location of the threat.
- One pilot was continuously behind the aircraft.
- IIMC provided task overload resulting in crash. FMS #2 failure added difficulty.
- Pilot on the controls was unable to process desired pitch attitude setting caused by large changes in power setting which resulted in an unusual attitude that could not be recovered from.

TSCWL2 Comments:

- Aircrew worked well in dividing the workload and communicating actions a majority of the time. The crew failed to verbalize actions in off-tuning.
- NAVAIDS on a few occasions. Overall satisfactory on crew coordination.
- Excellent crew coordination during IIMC and during instrument procedures and approach. Use of MFD pages excellent.
- Crew worked well together in managing the flight and identifying and separating crew responsibilities of the pilot on the controls and non-flying pilot.
- Crew coordination was overall satisfactory. At one point during the mission change prior to ACP10 both crew members were inside briefly sending a JVMF message and pilot on the controls changing plight plan to reflect mission change.
- Crew coordination was below previously set standard. The crew failed to manage avionics frequencies IAW the execution matrix.
- Crew did not always announce actions and intentions.
- Excellent crew coordination. The left and right digital maps had dissimilar displays. They were able to discuss and work around the problem.
- Difficulty troubleshooting MFD/FMS problem.
- Crew coordination failed to provide SA information until a decision was made. Ex. Departing the LZ direct to the FARP was planned, but not executed. There was no mention of the change until the PIC announced take for SP8.
- Good crew coordination throughout mission.
- Excellent crew coordination for diagnosing the EP and maintaining aircraft control. During the emergency procedure the crew climbed approximately 2000 ft AGL. This is contributed to the long approach and delay in landing the aircraft. Suspect the pilot on the controls was distracted by the EP.
- Greater crew coordination may have resulted in a successful recovery from the unusual attitude with the non-flying pilot calling out pitch, power, trim, and airspeed to aid in aircraft recovery.

TSC SA Comments:

- During the departure procedure the crew failed to maintain course alignment tracking to EMRUD. The crew was aware of the error, but failed to make the necessary corrections. Once the crew was vectored for correction they were able to regain situational awareness.
- Crew briefly lost situational awareness while performing ILS approach into Bike Lake. The loss of situational awareness was contributed to misinterpretation of approach procedures.
- Tuned wrong COM frequency using remote collective switch.
- Had to convert threat location from MGRS to Lat/Long.
- Departing the LZ for the FARP, the crew departed to the northeast instead of southwest to the FARP. Aircrew may have suffered from lack of exposure to the CTB. The crew hadn't been in the CTB in five days.
- All JVMF MSG & were viewed as "pending", during later of mission crew asked for acknowledge for position reports.
- Last JVMF MSG went unnoticed. No visual indicator. Possible instrumentation failure. (Note: Indicator light failure previously identified.)

- At one point Chalk Three reported loss of visual contact with Flight One and Two. Was unable to determine if the cause was due to separation by distance, being obscured by terrain, or weather.
- Very aware of terrain in poor weather with digital map.

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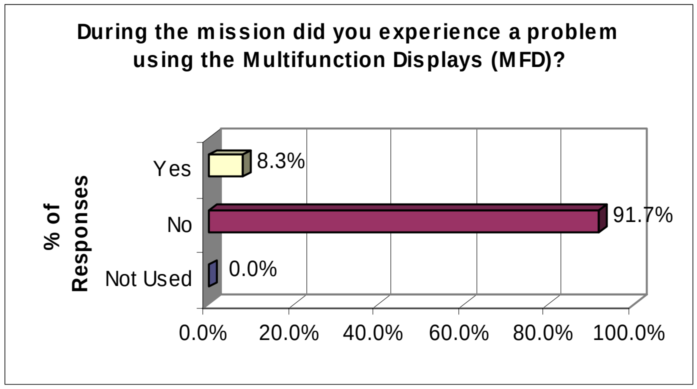
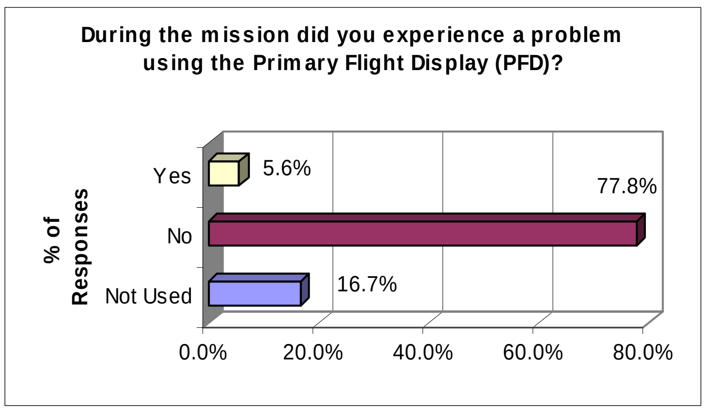
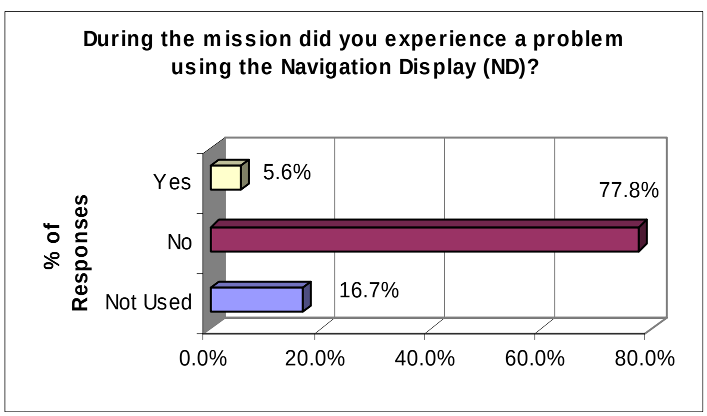
Appendix J. Pilot PVI Summary and Comments

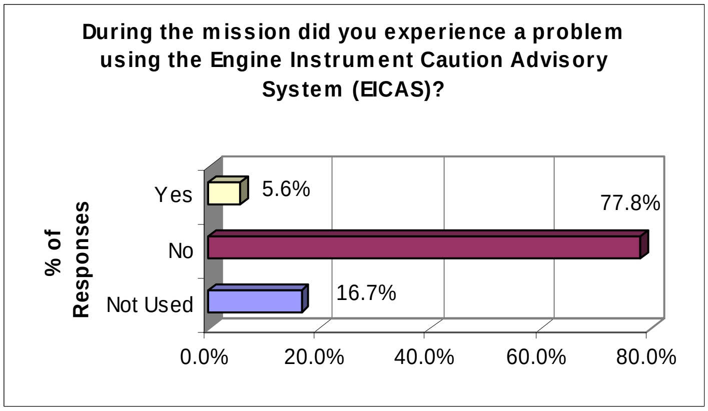
Pilot PVI Comments

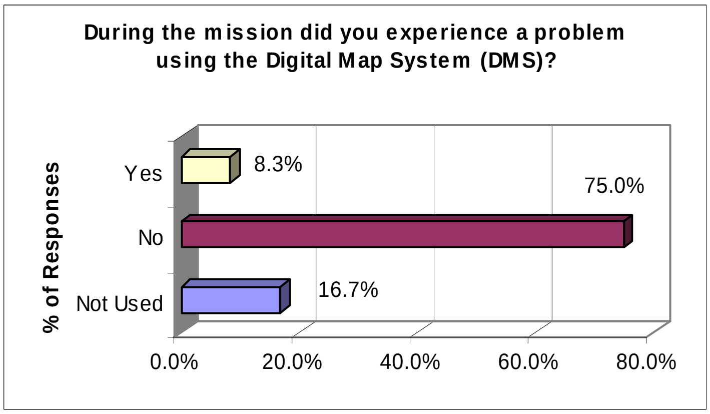
PV1:

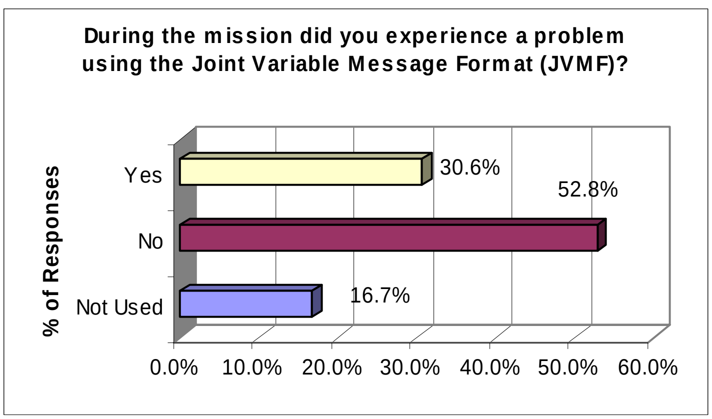


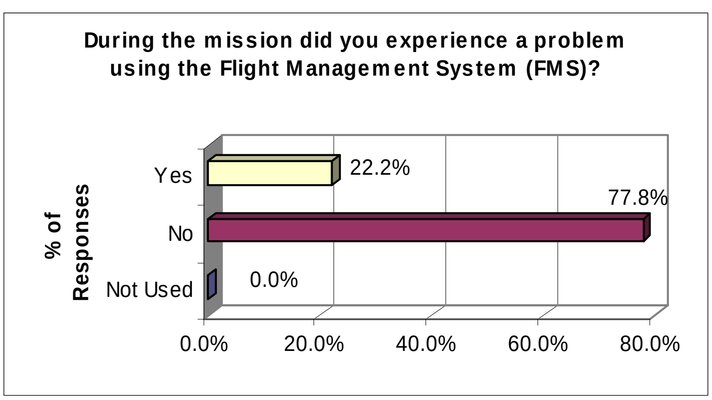


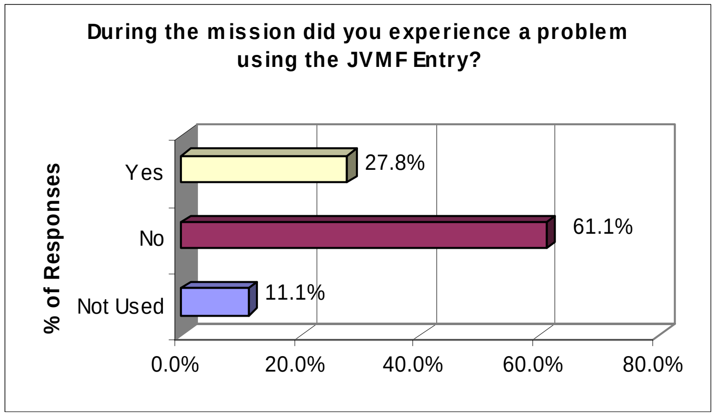


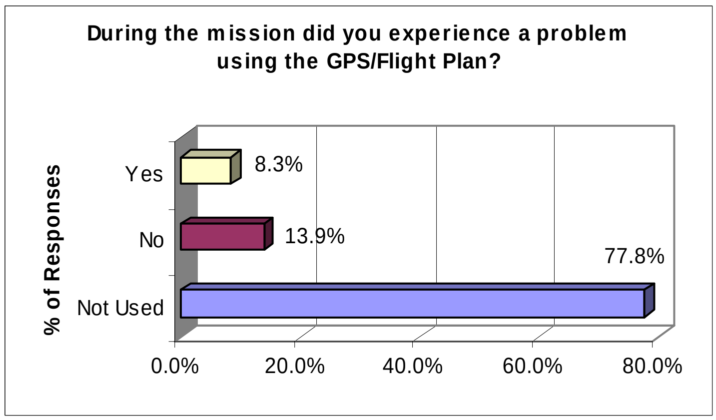

During the mission did you experience a problem using the Engine Instrument Caution Advisory System (EICAS)?
% of Responses
Yes
No
Not Used
5.6%
77.8%
16.7%
0.0%
20.0%
40.0%
60.0%
80.0%

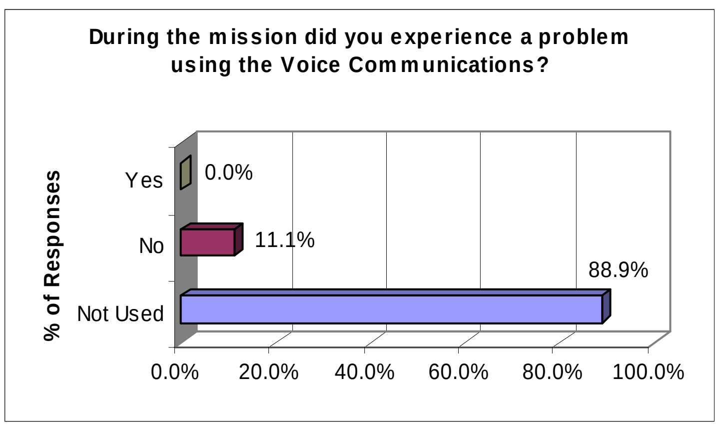

During the mission did you experience a problem using the Digital Map System (DMS)?
% of Responses
Yes
No
Not Used
8.3%
75.0%
16.7%
0.0%
20.0%
40.0%
60.0%
80.0%

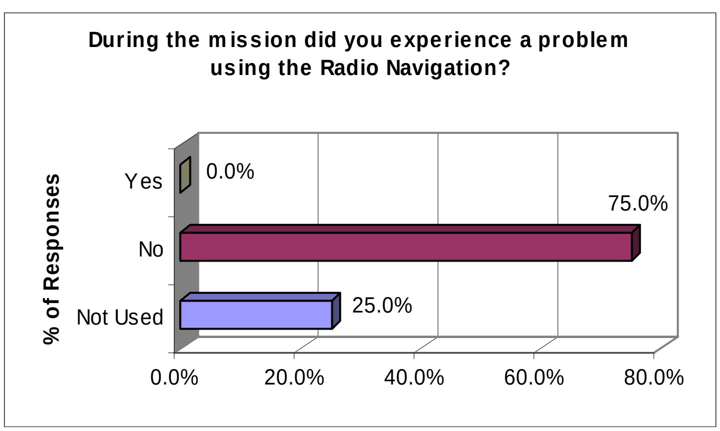

During the mission did you experience a problem using the Joint Variable Message Format (JVMF)?
% of Responses
Yes
No
Not Used
30.6%
52.8%
16.7%
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%

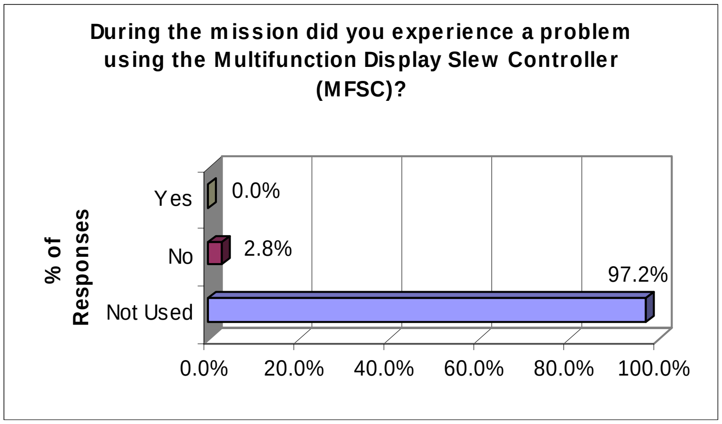

During the mission did you experience a problem using the Flight Management System (FMS)?
% of Responses
Yes
No
Not Used
22.2%
77.8%
0.0%
0.0%
20.0%
40.0%
60.0%
80.0%

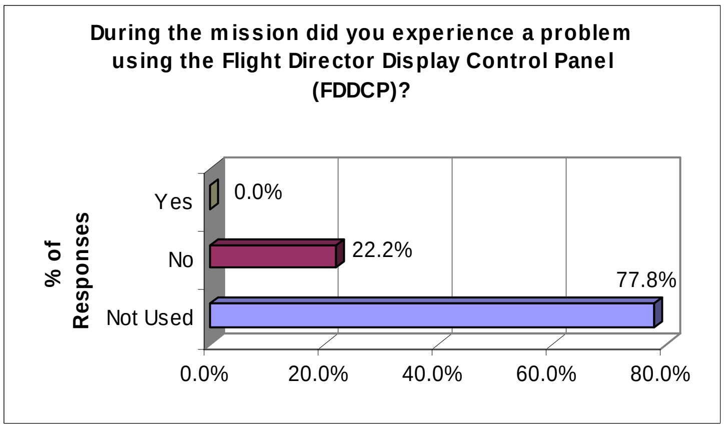

During the mission did you experience a problem using the JVMF Entry?
% of Responses
Yes
No
Not Used
27.8%
61.1%
11.1%
0.0%
20.0%
40.0%
60.0%
80.0%


During the mission did you experience a problem using the GPS/Flight Plan?
% of Responses
Yes
No
Not Used
8.3%
13.9%
77.8%
0.0%
20.0%
40.0%
60.0%
80.0%


During the mission did you experience a problem using the Voice Communications?
% of Responses
Yes
No
Not Used
0.0%
11.1%
88.9%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


During the mission did you experience a problem using the Radio Navigation?
% of Responses
Yes
No
Not Used
0.0%
75.0%
25.0%
0.0%
20.0%
40.0%
60.0%
80.0%

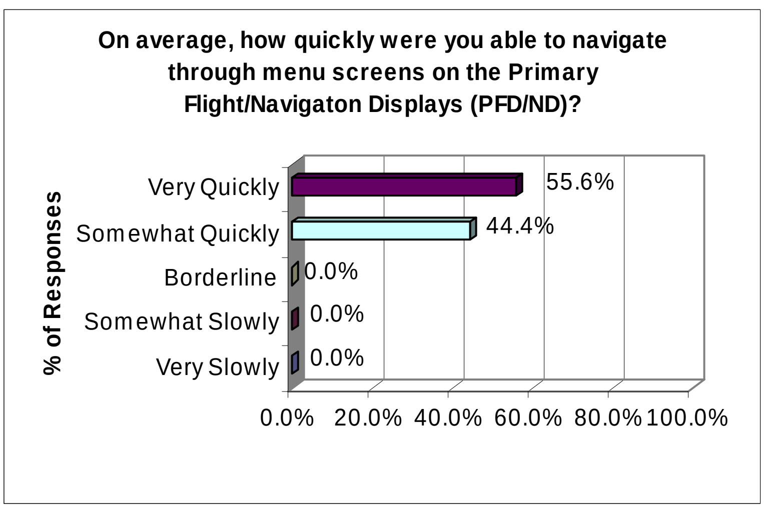


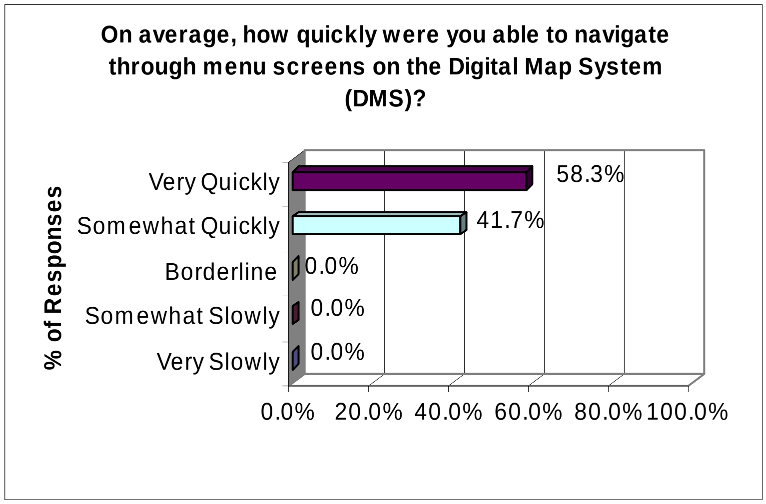


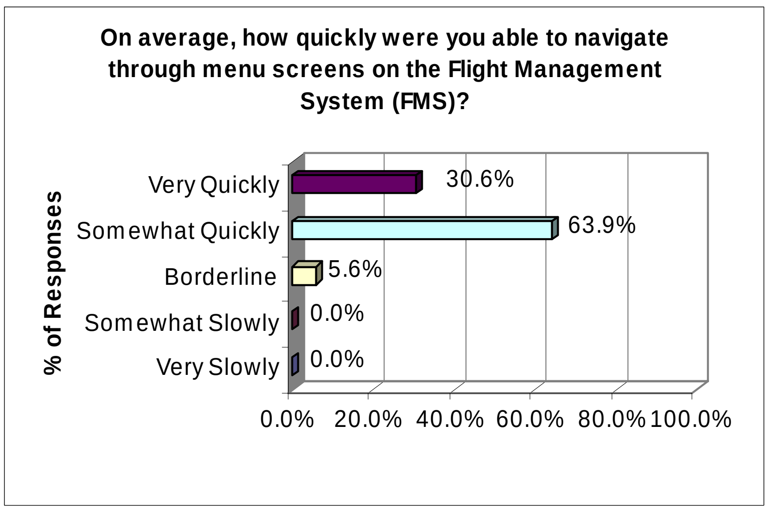
- EICAS – 0-100% scale and a PPC readout would be great.
- JVMF - Just too difficult, work is intense and the head is inside.
- JVMF – Net set up too difficult.
- JVMF – Took time to figure out why a message "timed out" only to realize that a limitation in the system (Manually entering the net) led to user error. Should look for a net automatically when I switch to another data frequency.
- JVMF Entry – If I could backspace it would save time. Currently if I need to backspace a letter, pushing the "CLR" key kills my errors message.
- The JVMF needs work. I needed to review a message I sent and there was no easy way to do it.
- JVMF locked up once, had to turn it off and then reset.
- When using switches T1-T6 my arm obstructs the view of the MFD. Recommend: (Use L1-L6 or R1-R6 for JVMF tasks).
- Incoming message reverse video does not get my attention if MFD is on anything other than JVMF page.
- You can easily miss an incoming message because there is no way to notify you.
- Digital Map – Failure of RH Pilot.
- MFD – At one point my MFD began feeding false information concerning my course and position. Once I realized I could isolate my MFD to the other MFD/FMS.
- FMS – When I reloaded the flight plan, my FMS would not update my position correctly.

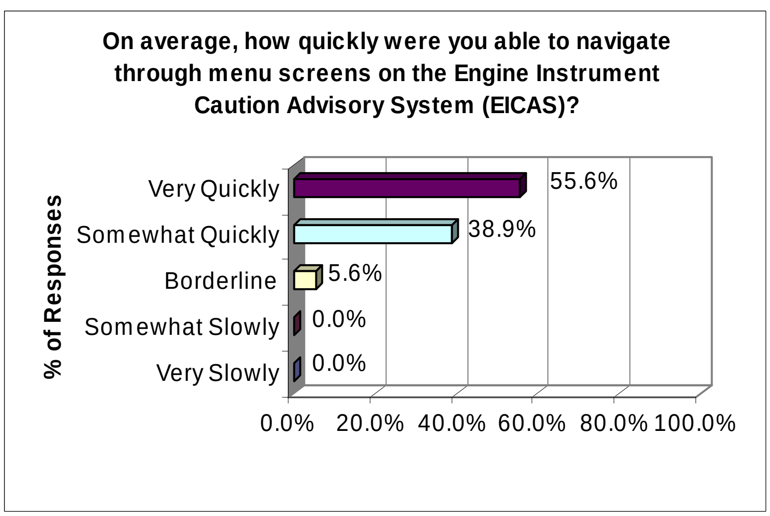
- JVMF – At one point I could not get JVMF to switch to a different net until I reinitialized the entire JVMF.
- JVMF was time consuming; the messages that were sent did not go through. Writing free text was also time consuming.
- Several times during the mission my NAV source would change from FMS to VOR. It was easy to change back, but it shouldn't have changed.
- The inbox does not queue the crew member that a message is in the box. An improvement may be any form of visual or audio that is proactive in alerting the crew.
- JVMF Entry – I have to keep hitting "ENT" on the FMS when I mean to press "SPACE" due to it's close proximity and I am hurrying to relay information.
- While JVMF XMIT menu is up and a Caution alert box comes up, when you select "CNCL" it reverts your JVMF page to SETUP.
- JVMF messaging could be simplified by being able to do more while pushing fewer buttons and flipping through less pages.
- EICAS Page – If system pressure or temperature goes into red, symbology needs to turn red.
- IDM would not initialize on to net. Messages stayed in pending status.
- Too much time is needed to send a message and read messages.
- The #2 FMS locked up, freezing the dig-map, ARC view, and ground speed. I was unable to help my other pilot because I was trying to fix my problem.

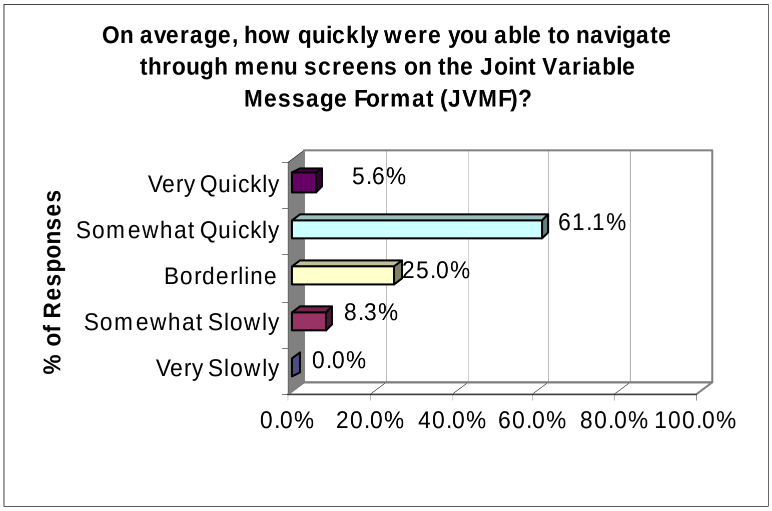
PV2:




On average, how quickly were you able to navigate through menu screens on the Digital Map System (DMS)?
% of Responses
Very Quickly
Somewhat Quickly
Borderline
Somewhat Slowly
Very Slowly
58.3%
41.7%
0.0%
0.0%
0.0%
0.0% 20.0% 40.0% 60.0% 80.0% 100.0%

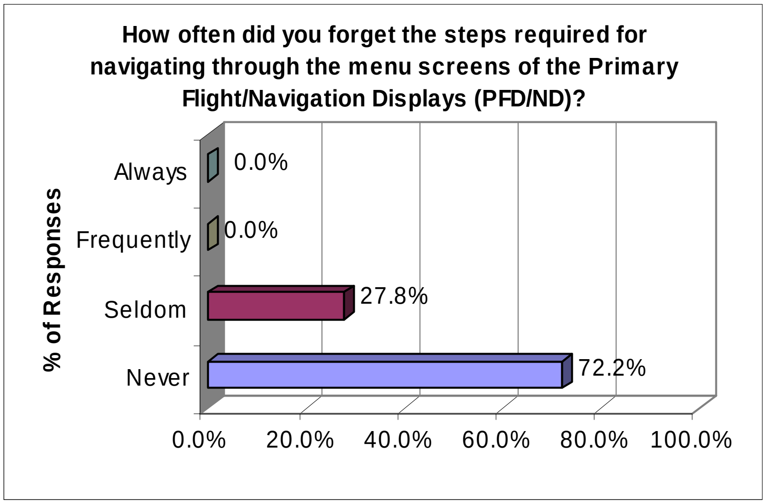

On average, how quickly were you able to navigate through menu screens on the Flight Management System (FMS)?
% of Responses
Very Quickly
Somewhat Quickly
Borderline
Somewhat Slowly
Very Slowly
30.6%
63.9%
5.6%
0.0%
0.0%
0.0% 20.0% 40.0% 60.0% 80.0% 100.0%

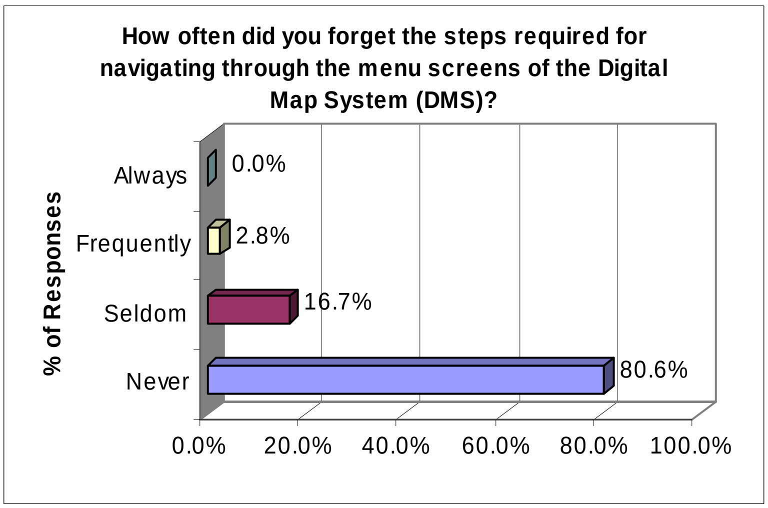

On average, how quickly were you able to navigate through menu screens on the Engine Instrument Caution Advisory System (EICAS)?
% of Responses
Very Quickly
Somewhat Quickly
Borderline
Somewhat Slowly
Very Slowly
55.6%
38.9%
5.6%
0.0%
0.0%
0.0% 20.0% 40.0% 60.0% 80.0% 100.0%

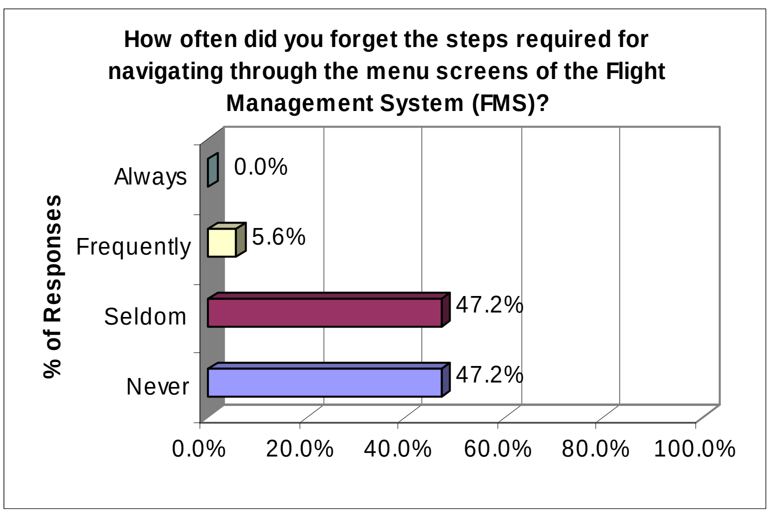


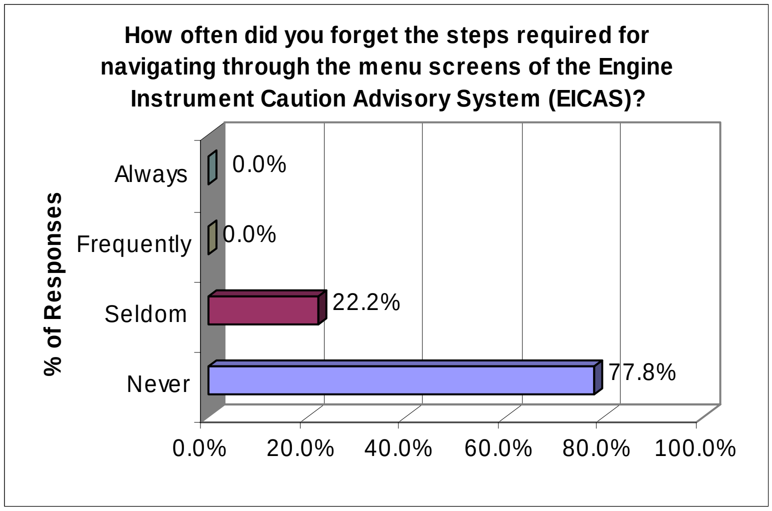
- JVMF inability to join a new TI Net automatically.
- Too much head inside time. Must set up, enter, then page to proper places. Message and keyboarding free texts takes time.
- FMS has too many buttons.
- JVMF has too many screens to get the info I want.
- On JVMF many of the most used buttons are on the top and you have to move your arm each time you use them. Look at putting these buttons on the side.
- EICAS process of numbers was slow. If system limits were set at 0-100% quick view would be possible.
- JVMF process is detailed the enter key when selected blocks the view of the MFD screen.
- EICAS – Didn't focus fine limit #'s, digital readouts good just limit lines hard to see Mopp/(No Glasses)
- JVMF – Just difficult to join net all those functions should be automatic
- The JVMF pages could be simplified to a point where most of the pertinent information needed for it's use and operation is on the initial page.
- JVMF enter button is at the top left. I had to relocate my hand to view screen after making a selection.
- There are too many pages on the JVMF function.

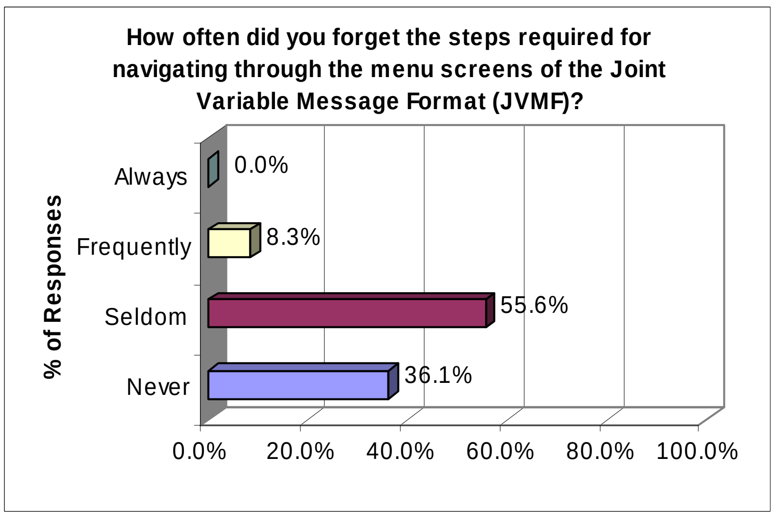
PV3:


How often did you forget the steps required for navigating through the menu screens of the Primary Flight/Navigation Displays (PFD/ND)?
% of Responses
Always
Frequently
Seldom
Never
0.0%
0.0%
27.8%
72.2%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


How often did you forget the steps required for navigating through the menu screens of the Digital Map System (DMS)?
% of Responses
Always
Frequently
Seldom
Never
0.0%
2.8%
16.7%
80.6%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

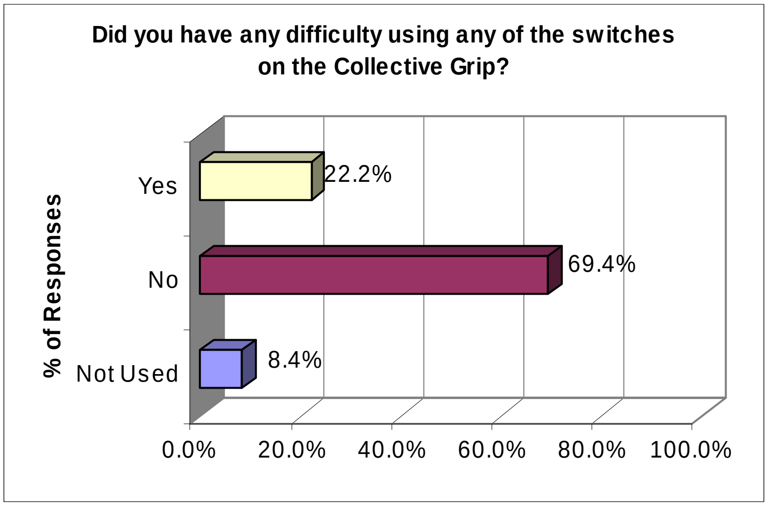

How often did you forget the steps required for navigating through the menu screens of the Flight Management System (FMS)?
% of Responses
Always
Frequently
Seldom
Never
0.0%
5.6%
47.2%
47.2%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

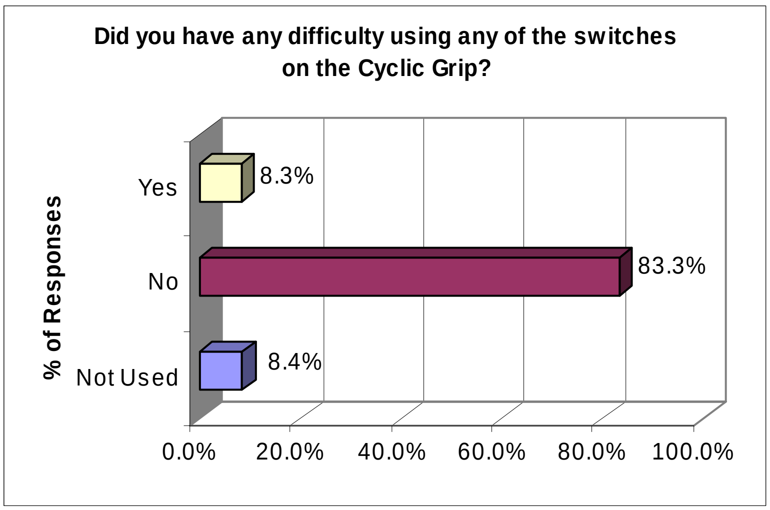




- Spending time looking for proper sequences. A "Loop" forms where I can't get to what I want, I have to stop and page through stuff.
- JVMF inability to join a new TI Net automatically.
- JVMF – Should be easier. Set frequency and system finds and join's everything like cell phone.
- I did forget how to navigate through the GPS waypoint pages.

PV5:

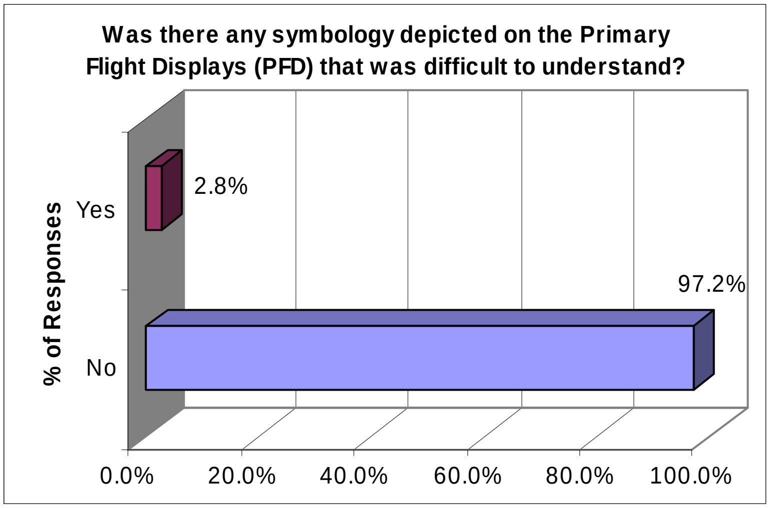


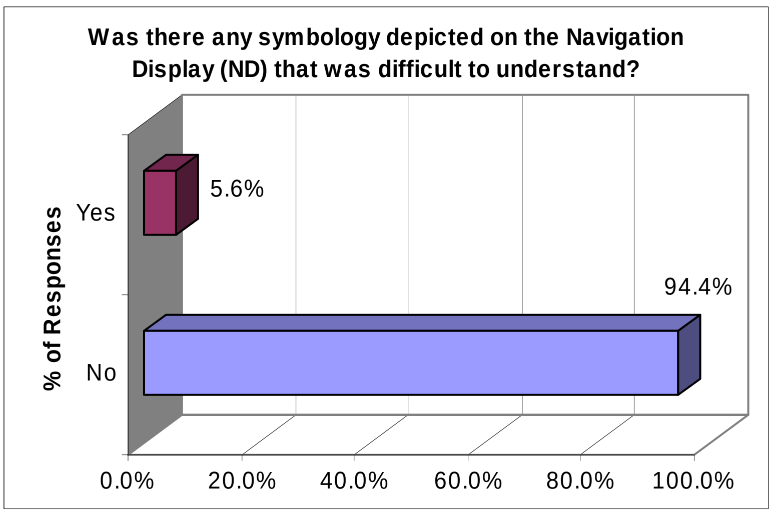


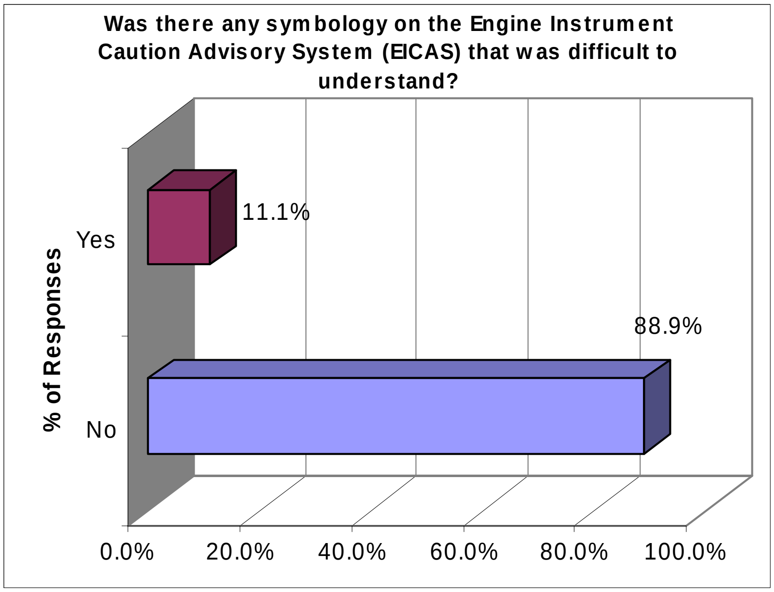
- These sticks are very intuitive and they fit your hand very well.
- The Radio Remote button should be reversed i.e. push up to scroll up.
- Frequency select switch on the collective is backwards. To change frequencies it should be push up to scroll up.
- MOPP – Gloves/ Pilot gloves size 12 pilots- just not big enough / Large MOPP – just not big enough
- The preset change switch on the collective seems to be backwards. (ie: “UP” moves the preset down and vice versa)
- The preset comm. Frequency slew switch on the collective increases the preset number when it is pulled back. This is backwards in my crew procedures. [Forward = UP and Back = Down] to me.
- While in MOPP 4, my right hand became fatigued and sensitivity was lost during the mission. I had problems placing my hand comfortably on the cyclic especially with the cyclic mounted stabilator slew-up switch.
- The freq select switch is wrong.
- Collective Freq select switch as before on all missions.

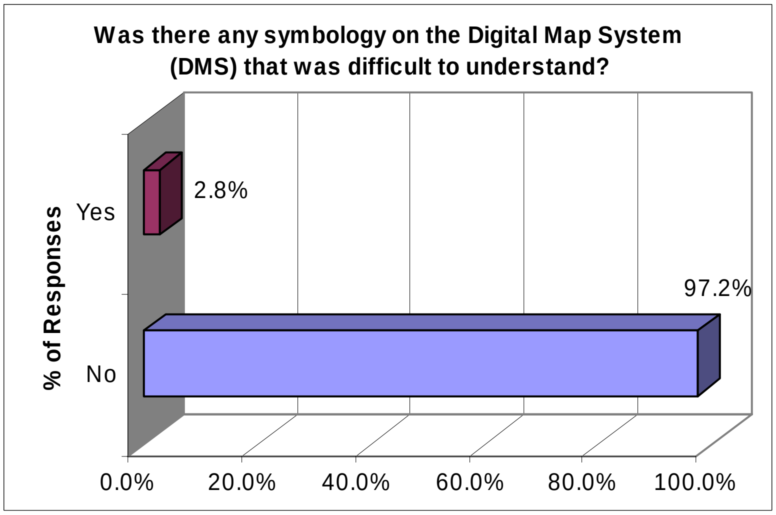
- During MOPP 4, three layers of gloves made the cyclic cramped.

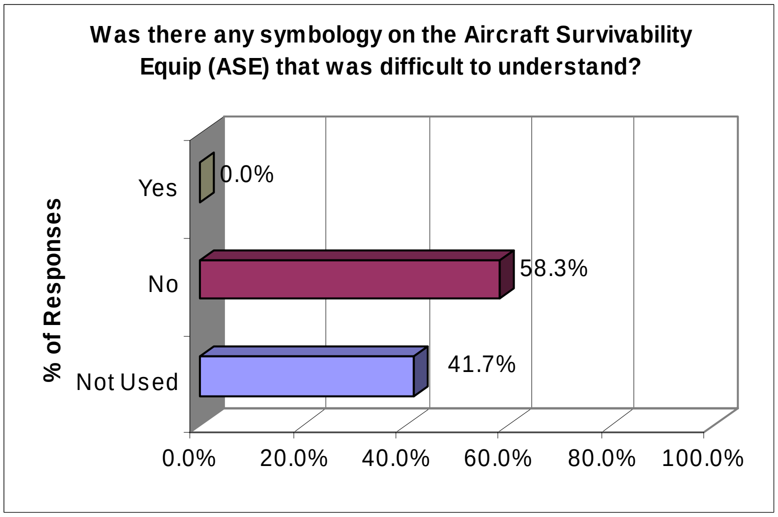
PV6:





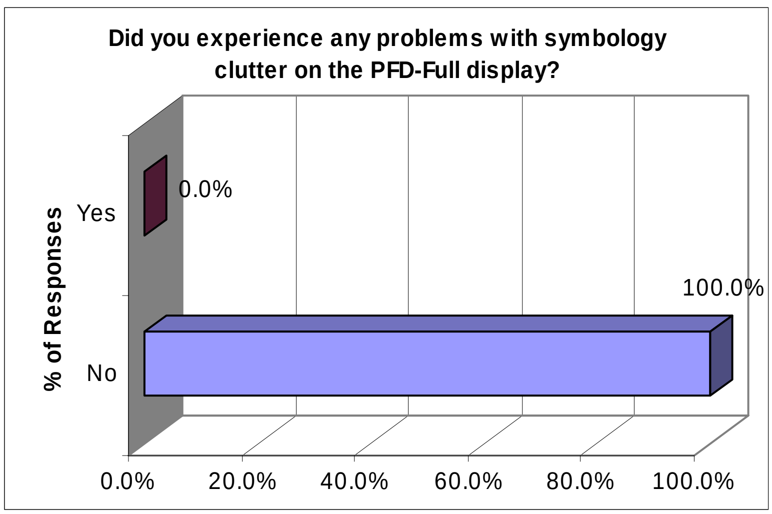

Was there any symbology on the Engine Instrument Caution Advisory System (EICAS) that was difficult to understand?
% of Responses
Yes
No
11.1%
88.9%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

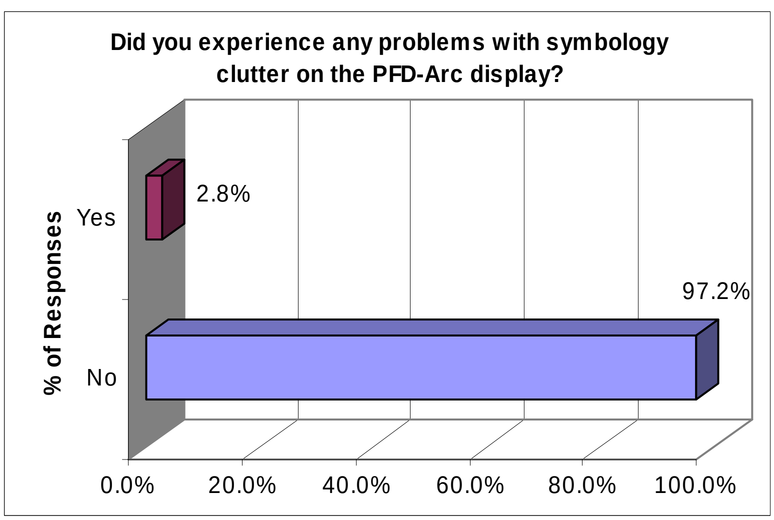

Was there any symbology on the Digital Map System (DMS) that was difficult to understand?
% of Responses
Yes
No
2.8%
97.2%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

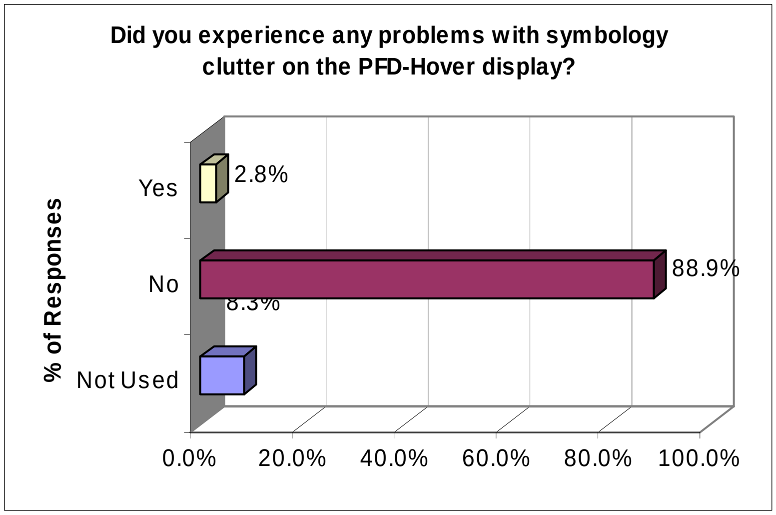

Was there any symbology on the Aircraft Survivability Equip (ASE) that was difficult to understand?
% of Responses
Yes
No
Not Used
0.0%
58.3%
41.7%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

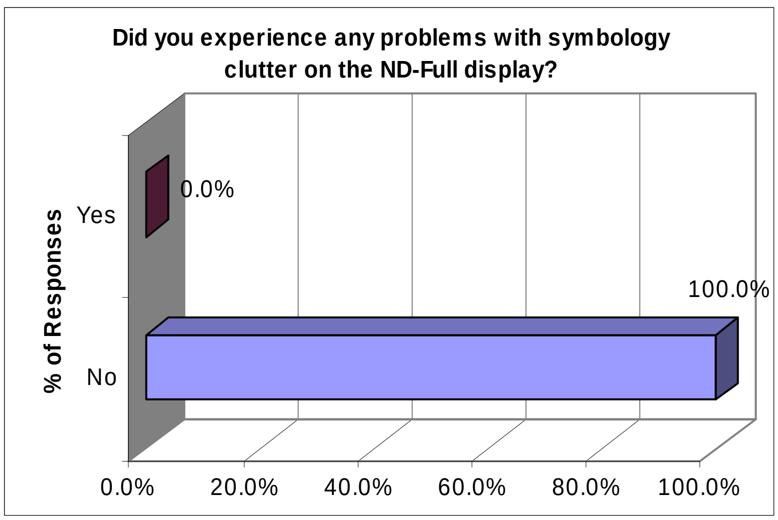
- I have to closely look at the scale marking 0-100%. All scales give growth.
- EICAS: system limits should be based on 0-100% (Green/Yellow/Red) not specific numbers.
- EICAS – Limit lines hard to see, 0-100% for all
- ND / DMS – When my MFD/FMS malfunctioned it took me some time to remember how to isolate to the other system since I had not experience this failure before.
- While using the gas mask. I had to make a more noticeable effort to tilt my head down to scan the current G/S readout. Placing the G/S a little higher on the MFD/PFD would take care of this.
- 0-100%. Chapter 5 limits are not really required to be memorized.
- Yellow scale lines tended to mix with yellow scale. (Proposed fix: Make a box around the yellow limit and let scale move through.)
- Aircraft icon on ND screen needs to be a color other than white so that it does not blend with colors on the map.

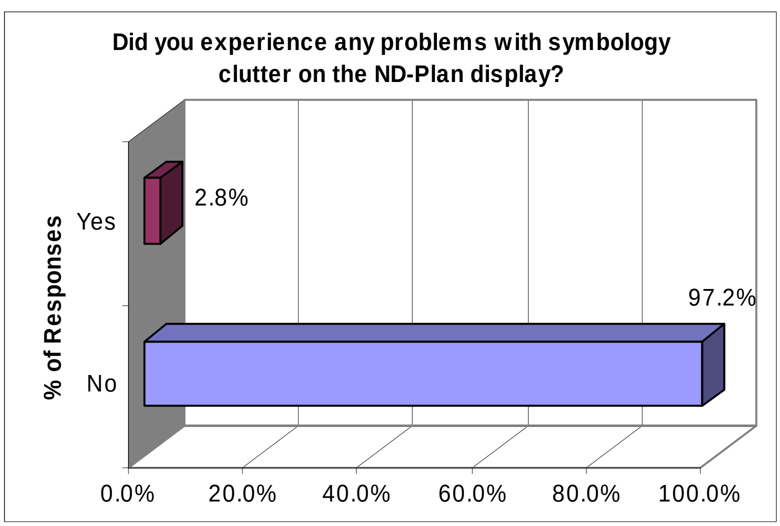
PV7:

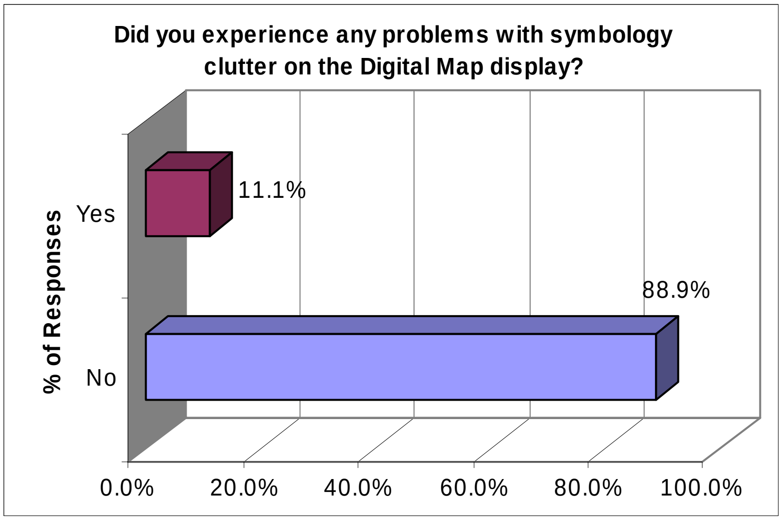





Did you experience any problems with symbology clutter on the PFD-Hover display?
% of Responses
Yes
No
Not Used
2.8%
88.9%
8.3%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

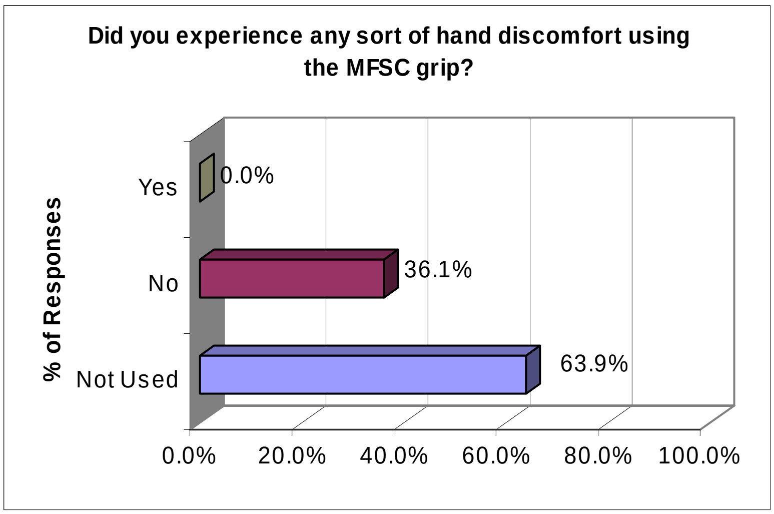

Did you experience any problems with symbology clutter on the ND-Full display?
% of Responses
Yes
No
0.0%
100.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

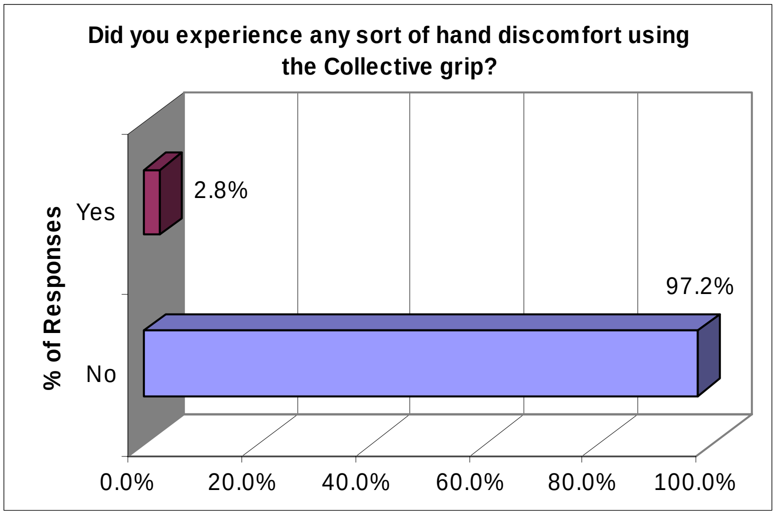

Did you experience any problems with symbology clutter on the ND-Plan display?
% of Responses
Yes
No
2.8%
97.2%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%

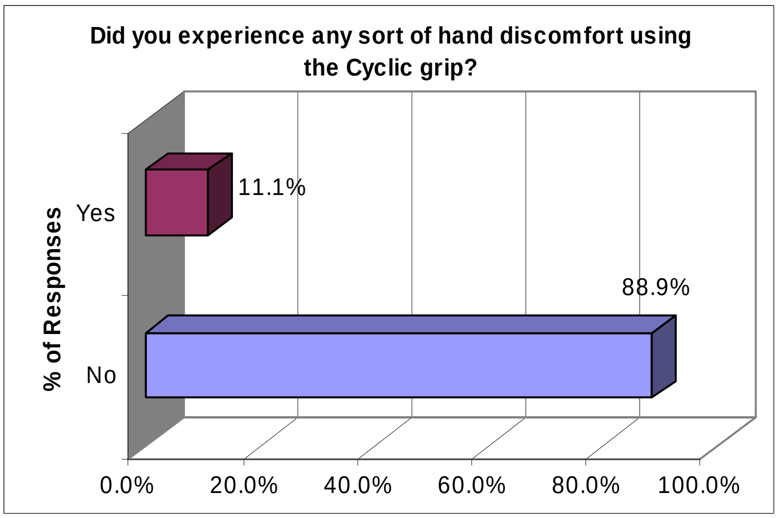


- ND / DMS – When my MFD/FMS malfunctioned it took me some time to remember how to isolate to the other system since I had not experience this failure before.
- I don't think the hover page help much.
- On the D-map, labels would block each other from viewing and the D-map scale goes from 10 to 20. Would be nice to have a 15 in there.
- When scaled out to 20 on the radius ring labels overwrite each other. Make it so they don't overwrite each other.
- When the #2 FMS locked up, I lost my digmap, ARC view, and ground speed on my MFD.

PV8:

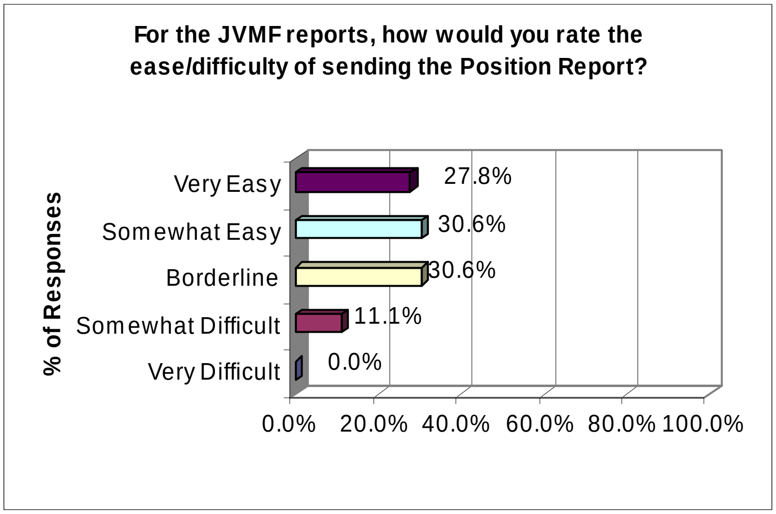


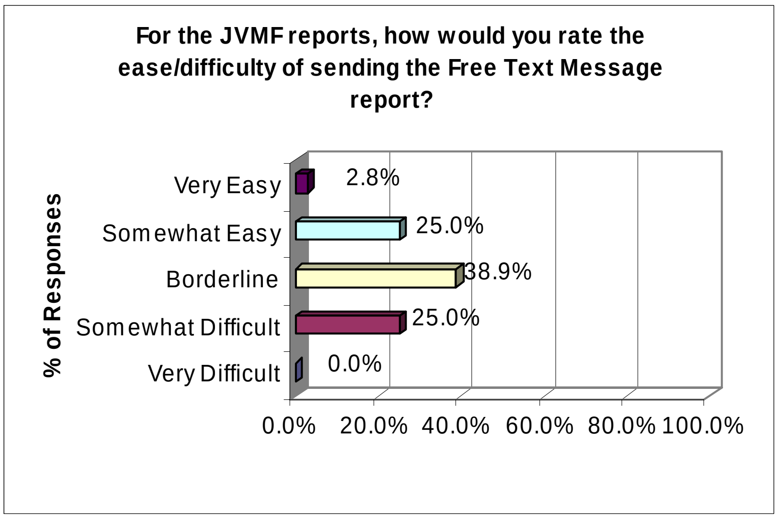




- The weapons release cover gets in the way of cyclic stick trim switch to the right.
- Yes, Due to MOPP 4 Level.
- My right hand barely fit around the cyclic with 3 layers of gloves and was cramped by the cyclic mounted stabilator slew-up switch.
- MOPP 4 with 3 layers of gloves – the cyclic is small and causes difficulty.

PV9:

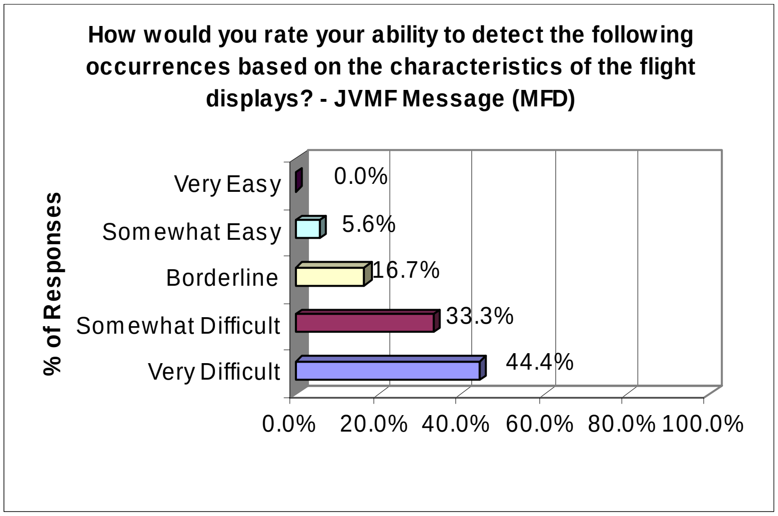


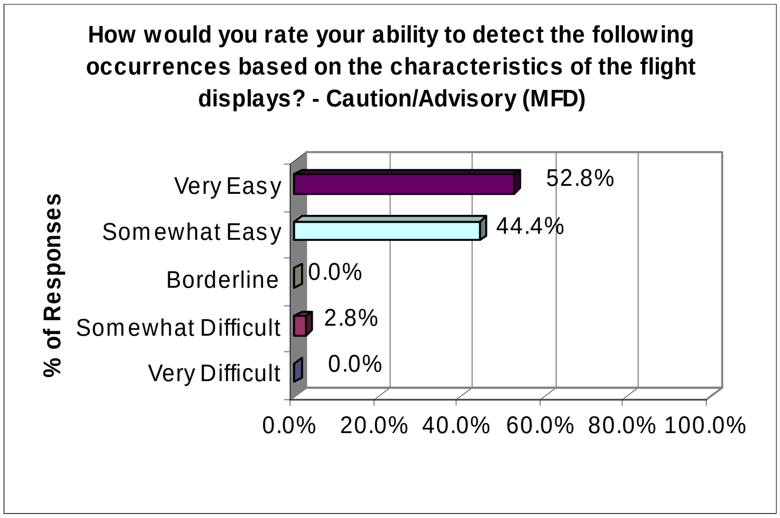


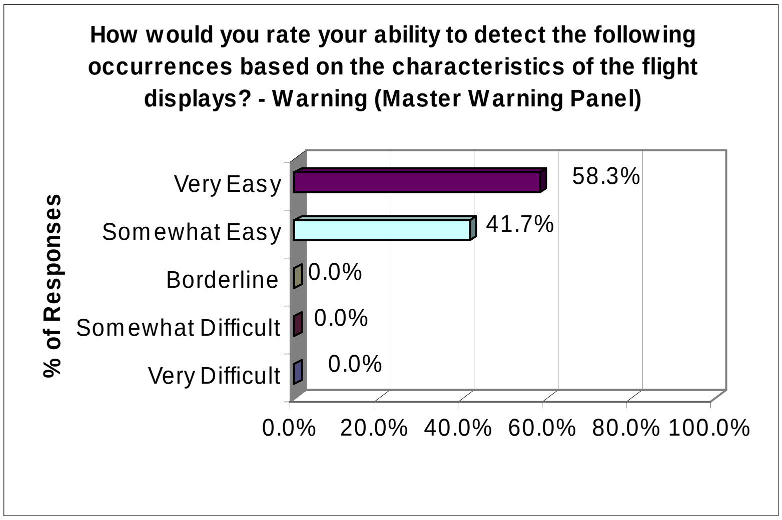
- Too much work inside.
- Too easy to select the wrong recipient.
- Backspace versus “CLR” ability when typing.
- It’s a high workload activity to punch in buttons and send messages. There are too many steps involved.
- Free text messages scroll down to free text then confirm then enter.
- I should be able to select free text then type.
- It takes time to fat finger text.
- Location of enter key, the arm blocks the screen. Time required to compute message, one crewmember is inside for long times.
- MOPP gloves were tight and wet inside liners
- Position reports could be cut down to a 1 or 2 step process free text messaging takes too much time.
- Having 3 layers of gloves on made me loose a little sensitivity of the fingers.
- I spent a little more time pushing buttons.
- JVMF should set up radios/nets.

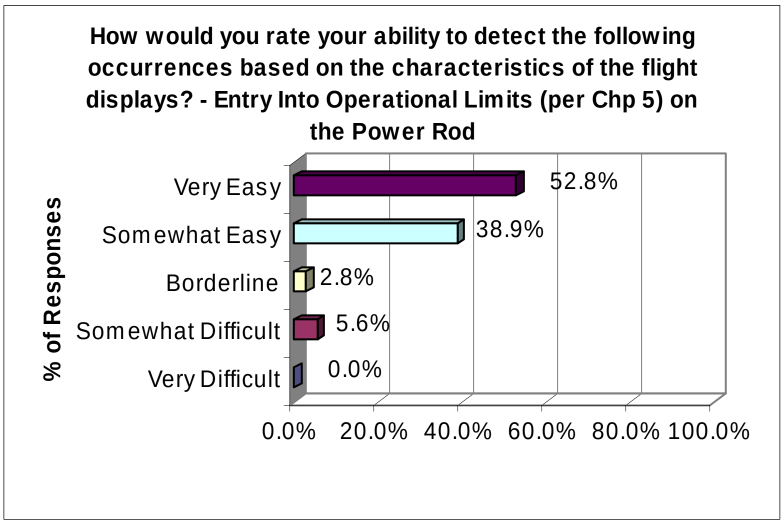
- Keyboard space – Space and Enter keys are too close.
- Free Text – When I am hurrying, I continuously press "ENT" when I mean to press "SPACE" due to the close proximity of the buttons.
- Free Text – Because of 3 layers of gloves, loss of sensitivity of fingers extra time was used to ensure accuracy of which buttons were pushed.
- Too much time spent inside the cockpit.
- Free text keeps one pilot "heads down" inside for several minutes at a time.
- Net entry should be easier (like a cell phone).
- Should be easier, less button presses – like bezzle button marked "position report" press it twice and send.
- Freetext – Slow and head down inside to do this.
- Too much time spent inside sending and typing reports.

PV10:









- Message alert is not easily recognizable.
- JVMF inverse video is inadequate – Suggest a limited border on the MFD that can be acknowledged.
- The JVMF indication was not big enough
- Reverse video on any page other than JVMF is not enough to catch my attention.
- You cannot tell when you have an incoming message.
- I have never seen the JVMF reverse video.
- JVMF – Just hard to see incoming messages.
- JVMF – Inverse video is not easily recognizable.
- There is not a good indication of when a JVMF message has come to your inbox.
- Difficult to ID JVMF.
- JVMF – Inverse video does not stand out enough to attract attention.
- Reverse video on incoming messages.
- The JVMF indication of an incoming message is not adequate.
- There is no good indication of an incoming message.
- No visible inbox when you have mail alert.
- JVMF – Light is hard to see, need better attention getter.

- Operating Limits – They are in the system and pilot no longer needs to have memorized.
- JVMF – Receiving a message is difficult to detect. Inverse video on JVMF is not enough to get your attention.
- Operational limits – after receiving a "Check EICAS" message I could not easily determine what the problem was until I noticed a change in digital number readout. Additionally, if the precautionary line changed to inverse video when the tape changed to yellow, I could have more easily determined how far into that range I was.
- The JVMF indication should be easier to detect. An outline on the inboard MFD that lights up when a message is received would be easier to detect.
- There is not a clean indication of an incoming message.
- JVMF inbox as ALL missions – the queue for inbox message is not visible.
- JVMF – Inverse video is difficult to detect.
- Hard to identify message in inbox.
- Inverse video on incoming message is hard to detect unless up on the Inbox screen.
- The indication of a message should be an outline on the inboard MFD that gives an option of coming back to check the message or to check it.
- There is no good indication of an incoming message.
- No visual queue for an incoming message.

Appendix K. Eye Tracker Results Summary

Out The Window

Left Seat
82.23% (VFR/FP/AM)
17.44% (VFR/NFP/AM)

89.32% (VFR/FP/MSM)
19.13% (VFR/NFP/MSM)

50.00% (VFR/FP/SSM)
16.43% (VFR/NFP/SSM)

Right Seat
88.50% (VFR/FP/AM)
41.71% (VFR/NFP/AM)

90.84% (VFR/FP/MSM)
42.92% (VFR/NFP/MSM)

80.44 (VFR/FP/SSM)
39.44% (VFR/NFP/SSM)

LMFD
8.49% (VFR/FP/AM)
25.60% (VFR/NFP/AM)

5.14% (VFR/FP/MSM)
24.16% (VFR/NFP/MSM)

23.73% (VFR/FP/SSM)
26.46% (VFR/NFP/SSM)

RMFD
6.10% (VFR/FP/AM)
32.49% (VFR/NFP/AM)

4.89% (VFR/FP/MSM)
29.88% (VFR/NFP/MSM)

11.64% (VFR/FP/SSM)
34.05% (VFR/NFP/SSM)

LMFD
1.86% (VFR/FP/AM)
15.47% (VFR/NFP/AM)

2.02% (VFR/FP/MSM)
13.47% (VFR/NFP/MSM)

1.31% (VFR/FP/SSM)
19.22% (VFR/NFP/SSM)

RMFD
5.79% (VFR/FP/AM)
18.76% (VFR/NFP/AM)

3.51% (VFR/FP/MSM)
12.64% (VFR/NFP/MSM)

13.63% (VFR/FP/SSM)
30.22% (VFR/NFP/SSM)

Other
3.17% (VFR/FP/AM)
24.47% (VFR/NFP/AM)

0.65% (VFR/FP/MSM)
26.82% (VFR/NFP/MSM)

14.64% (VFR/FP/SSM)
23.06% (VFR/NFP/SSM)

'Other' = primarily the area below the MFDs (e.g., FMS, kneeboard).

Other
3.85% (VFR/FP/AM)
24.06% (VFR/NFP/AM)

3.63% (VFR/FP/MSM)
30.97% (VFR/NFP/MSM)

4.63% (VFR/FP/SSM)
11.11% (VFR/NFP/SSM)

FP = Flying Pilot, NFP = Non-Flying Pilot, VFR = Visual Flight Rules, AM = All Missions, MSM = Multi-ship Missions, SSM = Single-Ship Mission, VFR Missions (single & multi-ship) = 7 missions (13.40 hours of data), VFR Missions (multi-ship only) = 5 missions (8.63 hours of data), VFR Missions (single-ship only) = 2 missions (4.76 hours of data), IFR data (Vignette 1) not valid.

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Glossary of Acronyms

AAR	after-action review
ACP	air control point
AOI	area of interest
ARL	Army Research Laboratory
ASL	Applied Science Laboratories
ATM	aircrew training manual
BHIVE	Battlefield Highly Immersive Virtual Environment
BWRS	Bedford Workload Rating Scale
CAAS	Common Avionics Architecture System
CPC	Comanche portable cockpit
CW	Chief Warrant
DCD	Directorate of Combat Developments
DIGMAP	digital mapping system
EDS	engineering development simulator
EICAS	engine instrument caution advisory system
EUD	early user demonstration
FMS	flight management system
HFE	human factors engineering
HRED	Human Research and Engineering Directorate
IFR	instrument flight rules
IIMC	inadvertent instrument meteorological conditions
IMC	instrumented meteorological conditions
JVMF	joint variable message format
LEUE	limited early user evaluation
LUT	limited user test
MANPRINT	manpower and personnel integration
MEDEVAC	medical evacuation
MFD	multi-function display
MP	mission profile
OMS	operational mode summary
OTW	out the window
PFD	primary flight display
PM	product manager
PMO	Product Manager's Office
PVI	pilot-vehicle interface
SA	situational awareness
SART	Situational Awareness Rating Technique
SED	Software Engineering Directorate

SIL	System Integration Laboratory
SSQ	Simulator Sickness Questionnaire
TRADOC	Training and Doctrine Command
TSC	tactical steering committee
TSM	TRADOC System Manager
UH	utility helicopter
VFR	visual flight rules
VMC	visual meteorological conditions
V&V	verification and validation
WSRT	Wilcoxon Signed Ranks Test
XP	experimental test pilot

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